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COMPUTER PROGRAM - CRYOGENIC STORAGE ON THE MOON (SUBROUTINES A AND C)

by JAMES K. HARRISON AND JAMES W. HILLIARD
Research Projects Laboratory
Computation Laboratory

NASA

George C. Marshall Space Flight Center, Huntsville, Alabama

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ABSTRACT

The details are given of a computer program which will compute the dimensions required for a heat transfer analysis of a cryogenic storage container on the moon. The container is divided into isothermal regions and the conducting path length and cross-sectional area are calculated for each. The container may vary in size and have three basic shapes: spherical, cylindrical with hemispherical ends and cylindrical with flat ends.

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RESEARCH PROJECTS LABORATORY

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SUMMARY

The details are given of a computer program which will compute the dimensions required for a heat transfer analysis of a cryogenic storage container on the moon. The container is divided into isothermal regions and the conducting path length and cross-sectional area are calculated for each. The container may vary in size and have three basic shapes: spherical, cylindrical with hemispherical ends and cylindrical with flat ends.

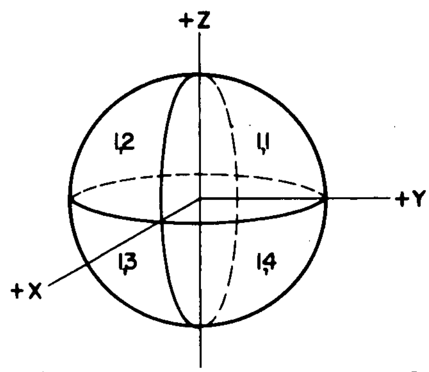
INTRODUCTION

The method of nodes in heat transfer calculations has become a familiar and useful tool for performing analysis where a nonuniform temperature exists. The method requires partitioning of the material into smaller regions or elements which, hopefully, will have, within the boundaries of each, a uniform temperature at any instant of time. Such uniformity, of course, will be more nearly achieved as the size of each region or element diminishes. The conducting path lengths and cross-sectional areas must be computed for each element. This computer program performs these calculations.

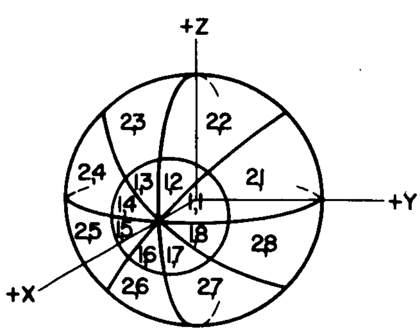
IDENTIFYING NOTATION AND PROGRAM DATA

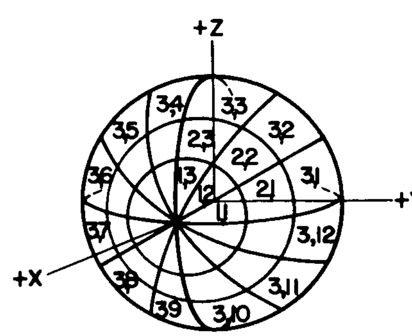
The surface of a storage vessel is imagined to be covered with a thermal insulation which is partioned into isothermal regions. The computer program can handle three vessel shapes: spherical, cylindrical with hemispherical ends, and cylindrical with flat ends. For each shape isothermal elements are constructed in three ways (Figs. 1-3). The number of elements for each case and identifying notation are given in Table I. If the insulation is divided into more than one layer the number of elements increase proportionately, i.e., two layers will double the number, three layers will triple the number, etc.

The coordinate system and numbering convention are shown in Figs. 1-3. When referring to a given element, i.e., E_{11}, the adjacent



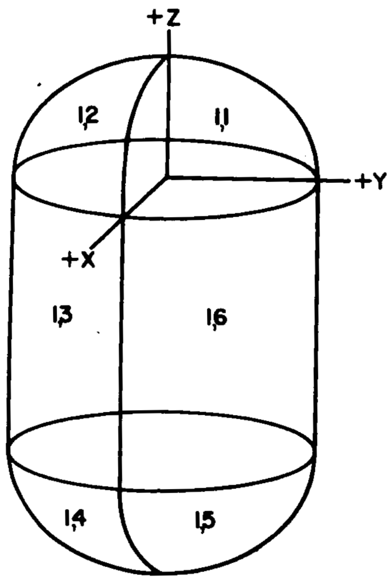
(a) N=8 - NUMBER OF ELEMENTS=8



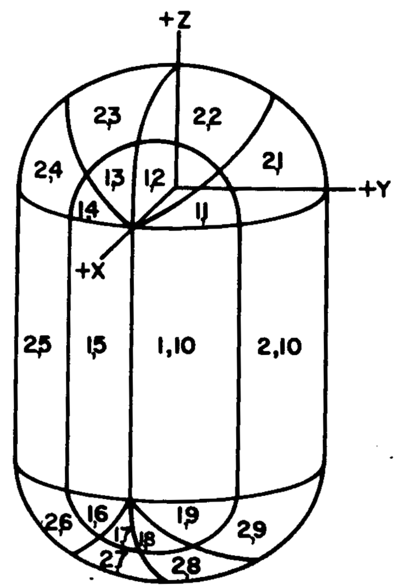


(b) N=32 - NUMBER OF ELEMENTS= 32 (c) N=72 - NUMBER OF ELEMENTS =72

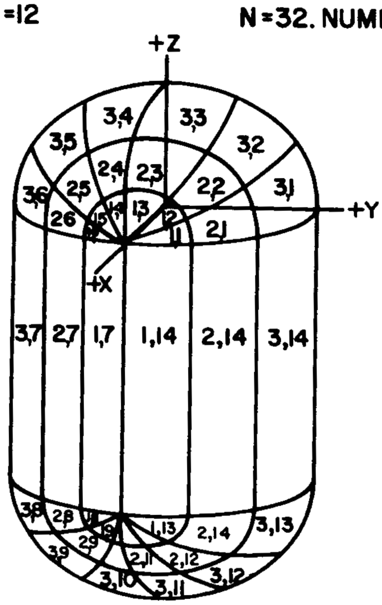
FIGURE 1 - SPHERE - CODE NUMBER = 0



N=8. NUMBER OF ELEMENTS=12
(a)



N=32. NUMBER OF ELEMENTS=40
(b)



N=72. NUMBER OF ELEMENTS =84
(c)

FIGURE 2 - CYLINDER WITH HEMISPHERICAL ENDS-CODE NUMBER = -1

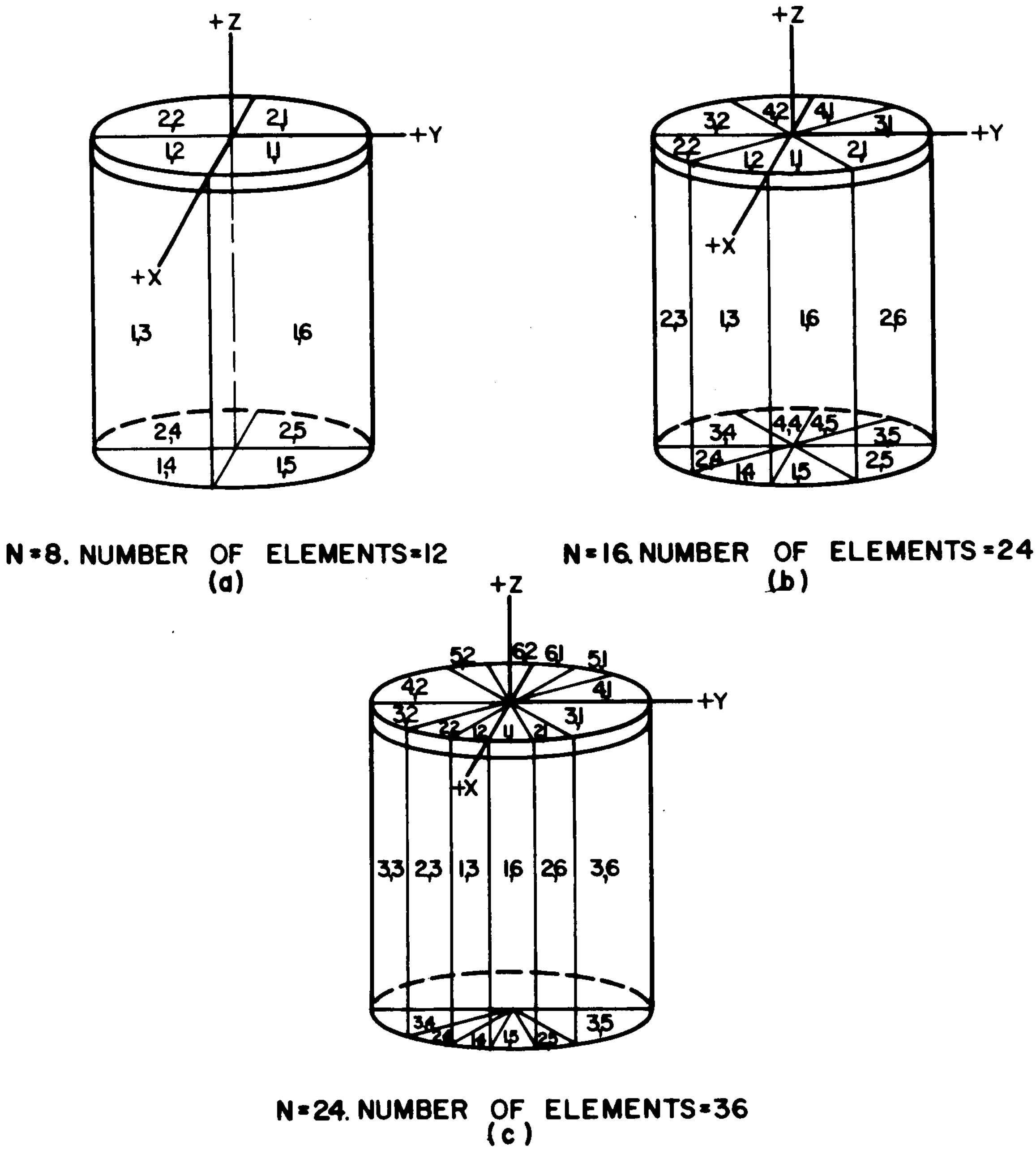


FIGURE 3. CYLINDER WITH FLAT ENDS – CODE NUMBER = +1

Table I

Identifying Notation and Elements for One Layer of Insulation

Shape	Sphere	Cylinder with Hemispherical Ends		Cylinder with Flat Ends
Code	0	-1		+1
N	Number of elements	Number of elements	N	Number of elements
8	8	12	8	12
32	32	40	16	24
72	72	84	24	36

elements are referred to in relation to E_{11} as left of, right of, front of, etc. For example, the conduction length in the direction to the right of E_{11} is indicated by lr_{11}. Figure 4 illustrates this. The convention is:

> right (r) - counterclockwise when viewing the container along the x-axis in the -x direction.
>
> front (f) - always toward the y-z plane in the direction that is the shorter distance, i.e., for E_{11}, front is toward E_{21}, but for E_{16} front is toward E_{26}.
>
> top (t) - in the direction from the inside toward the outside of the container.
>
> left, back, and under are in the directions counter to right, front and top, respectively.

The insulation is assumed to be divided into slices, sections, and layers. The symbol indices refer to this division. For example, E_{322} refers to the element (or region) located in the third slice, second section, and second layer.

The computer program input and output data are shown in Tables II and III, respectively.

The quantities in Table III are computed for each isothermal element. The required formulae are shown in Table IV. Because of the symmetrical arrangement of the elements, many quantities, once computed, may be used repeatedly as is shown in Table IV and in Table V.

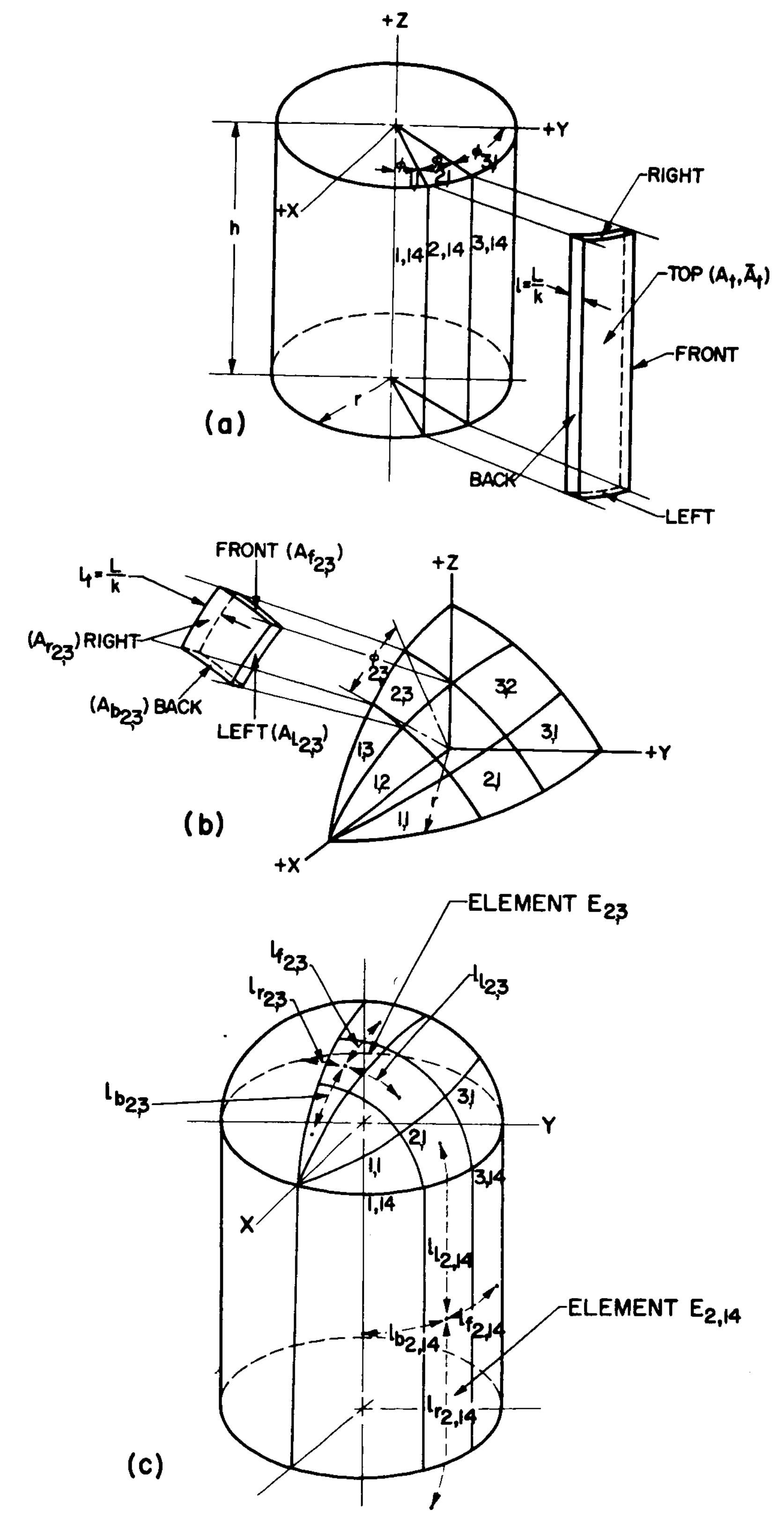


FIGURE 4 - CONVENTION USED WHEN REFERRING TO DIRECTIONS

Table II

Program Input Data

Formula Notation	Computer Language Notation	Remarks
N	N	Code to number of elements
J J	-	Indicates to computer when to stop
FIG	-	Indicates shape of container
L	A	Insulation thickness
h	H	Height of cylindrical part of container
r	R	Radius of container
k	B	Number of layers of insulation

Table III

Program Output Data

Notation	Remarks
$A\,f$	Cross-sectional area toward front
$A\,b$	Cross-sectional area toward back
$A\,l$	Cross-sectional area toward left
$A\,r$	Cross-sectional area toward right
$A\,t$	Cross-sectional area toward top side
$A\,u$	Cross-sectional area toward under side
$\bar{A}\,t$	Projected area of $A\,t$
$l\,f$	Conduction path length toward front
$l\,b$	Conduction path length toward back
$l\,l$	Conduction path length toward left
$l\,r$	Conduction path length toward right
$l\,t$	Conduction path length toward top side
$l\,u$	Conduction path length toward under side
V	Volume of isothermal element
Φ	Ratio of $A\,t$ to $\bar{A}\,t$
ϕ	Angle defined by Fig. 4. Computed to make all values of $A\,t$ equal.
α	Angle defined by Fig. 5. Used in computing $\vec{N}$
a	Angle defined by Fig. 5. Used in computing γ
b	Angle defined by Fig. 5. Used in computing $\vec{N}$
$\vec{N}$	Unit vector through center of isothermal element
$\vec{N}x$	x component of $\vec{N}$
$\vec{N}y$	y component of $\vec{N}$
$\vec{N}z$	z component of $\vec{N}$
γ	Angle defined by Fig. 6. Used in locating $\vec{N}$ with respect to -z direction.

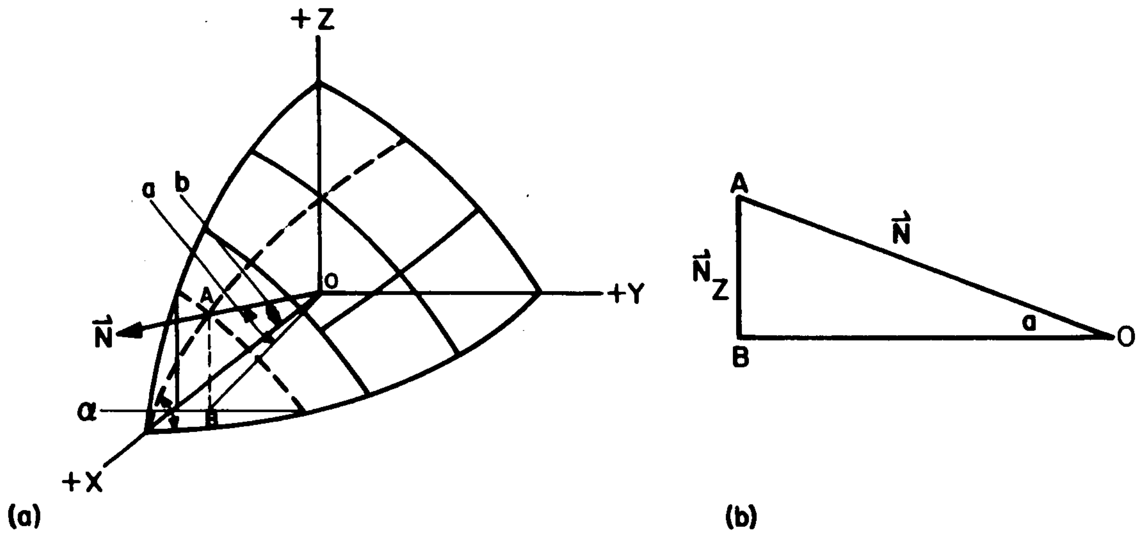


FIGURE 5 - ANGLES REQUIRED FOR COMPUTING $\vec{N}$.

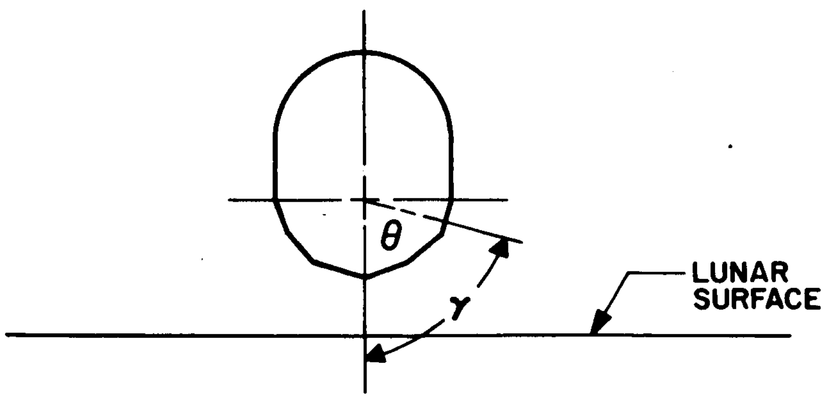


FIGURE 6 - ANGLE γ REQUIRED FOR GEOMETRICAL VIEW FACTOR

Table IV †

Formulae used in computing dimensions for storage vessel. Identifying notation is shown in Table I and II. Formulae cover all three shapes.

	N	SPHERE AND HEMISPHERICAL END									CYLINDRICAL MIDDLE		
		1,1	2,1	3,1	1,2	1,3	2,2	2,3	3,2	3,3	1,6; 1,10; 1,14	2,10; 2,14	3,14
ϕ	8	$\cos^{-1}(1-\frac{4\pi}{N\theta})$											
	32	$\cos^{-1}(1-\frac{4\pi}{N\theta})$	$\cos^{-1}(1-\frac{8\pi}{N\theta})-\phi_{1j}$		ϕ_{1j}		ϕ_{2j}						
	72	$\cos^{-1}(1-\frac{4\pi}{N\theta})$	$\cos^{-1}(1-\frac{8\pi}{N\theta})-\phi_{1j}$	$\frac{\pi}{2}-(\phi_{1j}+\phi_{2,j})$	ϕ_{1j}	ϕ_{1j}	ϕ_{2j}	ϕ_{2j}	ϕ_{3j}	ϕ_{3j}			
A_L	8	$r\phi_{1j}\frac{L}{k}(1-\frac{L}{2rk})$									$r\phi_{1j}\frac{L}{k}(1-\frac{L}{2kr})$		
	32	$r\phi_{1j}\frac{L}{k}(1-\frac{L}{2rk})$	$r\phi_{2j}\frac{L}{k}(1-\frac{L}{2rk})$		$A_{L_{1j}}$		$A_{L_{2j}}$				$r\phi_{1j}\frac{L}{k}(1-\frac{L}{2kr})$	$r\phi_{2j}\frac{L}{k}(1-\frac{L}{2kr})$	
	72	$r\phi_{1j}\frac{L}{k}(1-\frac{L}{2rk})$	$r\phi_{2j}\frac{L}{k}(1-\frac{L}{2rk})$	$r\phi_{3j}\frac{L}{k}(1-\frac{L}{2rk})$	$A_{L_{1j}}$	$A_{L_{1j}}$	$A_{L_{2j}}$	$A_{L_{2j}}$	$A_{L_{3j}}$	$A_{L_{3j}}$	$r\phi_{1j}\frac{L}{k}(1-\frac{L}{2kr})$	$r\phi_{2j}\frac{L}{k}(1-\frac{L}{2kr})$	$r\phi_{3j}\frac{L}{k}(1-\frac{L}{2kr})$
A_r	8	$r\phi_{1j}\frac{L}{k}(1-\frac{L}{2rk})$									$A_{L_{1,6}}$		
	32	$r\phi_{1j}\frac{L}{k}(1-\frac{L}{2rk})$	$A_{L_{2j}}$		$A_{L_{1j}}$		$A_{L_{2j}}$				$A_{L_{1,10}}$	$A_{L_{2,10}}$	
	72	$r\phi_{1j}\frac{L}{k}(1-\frac{L}{2rk})$	$A_{L_{2j}}$	$A_{L_{3j}}$	$A_{L_{1j}}$	$A_{L_{1j}}$	$A_{L_{2j}}$	$A_{L_{2j}}$	$A_{L_{3j}}$	$A_{L_{3j}}$	$A_{L_{1,14}}$	$A_{L_{2,14}}$	$A_{L_{3,14}}$
A_f	8	$\frac{rL\theta}{k}(\sin\phi_{1j}-\frac{L}{2kr})$									$h\frac{L}{k}$		
	32	$\frac{rL\theta}{k}(\sin\phi_{1j}-\frac{L}{2kr})$	$\frac{rL\theta}{k}\left[\sin(\phi_{1j}+\phi_{2j})-\frac{L}{2kr}\right]$		$A_{f_{1j}}$		$A_{f_{21}}$				$h\frac{L}{k}$	$h\frac{L}{k}$	
	72	$\frac{rL\theta}{k}(\sin\phi_{1j}-\frac{L}{2kr})$	$\frac{rL\theta}{k}\left[\sin(\phi_{1j}+\phi_{2j})-\frac{L}{2kr}\right]$	$\frac{rL\theta}{k}(1-\frac{L}{2kr})$	$A_{f_{1j}}$	$A_{f_{11}}$	$A_{f_{21}}$	$A_{f_{21}}$	$A_{f_{31}}$	$A_{f_{31}}$	$h\frac{L}{k}$	$h\frac{L}{k}$	$h\frac{L}{k}$
A_b	8	0									$A_{f_{1,6}}$		
	32	0	$A_{f_{1j}}$		$A_{b_{1j}}$		$A_{f_{2j}}$				$A_{f_{1,10}}$	$A_{f_{2,10}}$	
	72	0	$A_{f_{1j}}$	$A_{f_{2j}}$	$A_{b_{1j}}$	$A_{b_{1j}}$	$A_{f_{2j}}$	$A_{f_{2j}}$	$A_{f_{3j}}$	$A_{f_{3j}}$	$A_{f_{1,14}}$	$A_{f_{2,14}}$	$A_{f_{3,14}}$
A_t	8	$4\pi r^2/N$									$r\phi_{1j}h$		
	32	$4\pi r^2/N$	$4\pi r^2/N$		$A_{t_{1j}}$		$A_{t_{2j}}$				$r\phi_{1j}h$	$r\phi_{2j}h$	
	72	$4\pi r^2/N$	$4\pi r^2/N$	$4\pi r^2/N$	$A_{t_{1j}}$	$A_{t_{1j}}$	$A_{t_{2j}}$	$A_{t_{2j}}$	$A_{t_{3j}}$	$A_{t_{3j}}$	$r\phi_{1j}h$	$r\phi_{2j}h$	$r\phi_{3j}h$
A_u	8	$4\pi r^2/N$									$A_{t_{1,6}}$		
	32	$4\pi r^2/N$	$4\pi r^2/N$		$A_{u_{1j}}$		$A_{u_{2j}}$				$A_{t_{1,10}}$	$A_{t_{2,10}}$	
	72	$4\pi r^2/N$	$4\pi r^2/N$	$4\pi r^2/N$	$A_{u_{1j}}$	$A_{u_{1j}}$	$A_{u_{2j}}$	$A_{u_{2j}}$	$A_{u_{3j}}$	$A_{u_{3j}}$	$A_{t_{1,14}}$	$A_{t_{2,14}}$	$A_{t_{3,14}}$
$\bar{A}_t$	8	ΦA_t									$2r\sin(\phi_{1j}/2)h$		
	32	ΦA_t	ΦA_t		$\bar{A}_{t_{1j}}$		$\bar{A}_{t_{2j}}$				$2r\sin(\phi_{1j}/2)h$	$2r\sin(\phi_{2j}/2)h$	
	72	ΦA_t	ΦA_t	ΦA_t	$\bar{A}_{t_{1j}}$	$\bar{A}_{t_{1j}}$	$\bar{A}_{t_{2j}}$	$\bar{A}_{t_{2j}}$	$\bar{A}_{t_{3j}}$	$\bar{A}_{t_{3j}}$	$2r\sin(\phi_{1j}/2)h$	$2r\sin(\phi_{2j}/2)h$	$2r\sin(\phi_{3j}/2)h$

† SPHERE (CODE NUMBER 0) AND CYLINDRICAL MIDDLE WITH HEMISPHERICAL ENDS (CODE NUMBER -1.0)

Table IV† (Cont'd)

			SPHERE AND HEMISPHERICAL END									CYLINDRICAL MIDDLE		
		N	1,1	2,1	3,1	1,2	1,3	2,2	2,3	3,2	3,3	1,6; 1,10; 1,14	2,10; 2,14	3,14
L_L	SPHERE	8	$\frac{r\theta}{2}\sin\phi_{11}$											
		32	$\frac{r\theta}{2}\sin\phi_{11}$	$\frac{r\theta}{2}[\sin\phi_{11}+\sin(\phi_{11}+\phi_{21})]$		$L_{L_{11}}$		$L_{L_{21}}$						
		72	$\frac{r\theta}{2}\sin\phi_{11}$	$\frac{r\theta}{2}[\sin\phi_{11}+\sin(\phi_{11}+\phi_{21})]$	$\frac{r\theta}{2}[\sin(\phi_{11}+\phi_{21})+1]$	$L_{L_{11}}$	$L_{L_{11}}$	$L_{L_{21}}$	$L_{L_{21}}$	$L_{L_{31}}$	$L_{L_{31}}$			
L_r	SPHERE	8	$\frac{r\theta}{2}\sin\phi_{11}$											
		32	$\frac{r\theta}{2}\sin\phi_{11}$	$\frac{r\theta}{2}[\sin\phi_{11}+\sin(\phi_{11}+\phi_{21})]$		$L_{r_{11}}$		$L_{r_{21}}$						
		72	$\frac{r\theta}{2}\sin\phi_{11}$	$\frac{r\theta}{2}[\sin\phi_{11}+\sin(\phi_{11}+\phi_{21})]$	$\frac{r\theta}{2}[\sin(\phi_{11}+\phi_{21})+1]$	$L_{r_{11}}$	$L_{r_{11}}$	$L_{r_{21}}$	$L_{r_{21}}$	$L_{r_{31}}$	$L_{r_{31}}$			
L_L	HEMI-SPHERE	8	$\frac{h}{2}+\frac{r\theta}{4}\sin\phi_{11}$									$\frac{h}{2}+\frac{r\theta}{4}\sin\phi_{11}$		
		32	$\frac{h}{2}+\frac{r\theta}{4}\sin\phi_{11}$	$\frac{h}{2}+\frac{r\theta}{4}[\sin\phi_{11}+\sin(\phi_{11}+\phi_{21})]$		$L_{r_{11}}$		$L_{r_{1,2}}$				$\frac{h}{2}+\frac{r\theta}{4}\sin\phi_{11}$	$\frac{h}{2}+\frac{r\theta}{4}[\sin\phi_{11}+\sin(\phi_{11}+\phi_{21})]$	
		72	$\frac{h}{2}+\frac{r\theta}{4}\sin\phi_{11}$	$\frac{h}{2}+\frac{r\theta}{4}[\sin\phi_{11}+\sin(\phi_{11}+\phi_{21})]$	$\frac{h}{2}+\frac{r\theta}{4}[\sin(\phi_{11}+\phi_{21})+1]$	$L_{r_{11}}$	$L_{r_{11}}$	$L_{r_{21}}$	$L_{r_{21}}$	$L_{r_{31}}$	$L_{r_{31}}$	$\frac{h}{2}+\frac{r\theta}{4}\sin\phi_{11}$	$\frac{h}{2}+\frac{r\theta}{4}[\sin\phi_{11}+\sin(\phi_{11}+\phi_{21})]$	$\frac{h}{2}+\frac{r\theta}{4}[\sin(\phi_{11}+\phi_{21})+1]$
L_r	HEMI-SPHERE	8	$\frac{r\theta}{2}\sin\phi_{11}$									$L_{L_{1,6}}$		
		32	$\frac{r\theta}{2}\sin\phi_{11}$	$\frac{r\theta}{2}[\sin\phi_{11}+\sin(\phi_{11}+\phi_{21})]$		$L_{r_{11}}$		$L_{r_{21}}$				$L_{L_{1,10}}$	$L_{L_{2,10}}$	
		72	$\frac{r\theta}{2}\sin\phi_{11}$	$\frac{r\theta}{2}[\sin\phi+\sin(\phi_{11}+\phi_{21})]$	$\frac{r\theta}{2}[\sin(\phi_{11}+\phi_{21})+1]$	$L_{r_{11}}$	$L_{r_{11}}$	$L_{r_{21}}$	$L_{r_{21}}$	$L_{r_{31}}$	$L_{r_{31}}$	$L_{L_{1,14}}$	$L_{L_{2,14}}$	$L_{L_{3,14}}$
L_f		8	$r\phi_{11}$									$r\phi_{11}$		
		32	$\frac{r}{2}(\phi_{11}+\phi_{21})$	$r\phi_{21}$		$L_{f_{11}}$		$L_{f_{21}}$				$\frac{r}{2}(\phi_{11}+\phi_{21})$	$r\phi_{21}$	
		72	$\frac{r}{2}(\phi_{11}+\phi_{21})$	$\frac{r}{2}(\phi_{21}+\phi_{31})$	$r\phi_{31}$	$L_{f_{11}}$	$L_{f_{11}}$	$L_{f_{21}}$	$L_{f_{21}}$	$L_{f_{31}}$	$L_{f_{31}}$	$\frac{r}{2}(\phi_{11}+\phi_{21})$	$r(\phi_{21}+\phi_{31})$	$r\phi_{31}$
L_b		8	$\frac{r}{2}\phi_{11}$									$L_{f_{1,6}}$		
		32	$\frac{r}{2}\phi_{11}$	$L_{f_{11}}$		$L_{f_{11}}$		$L_{f_{21}}$				$r\phi_{11}$	$L_{f_{1,10}}$	
		72	$\frac{r}{2}\phi_{11}$	$L_{f_{11}}$	$L_{f_{21}}$	$L_{b_{11}}$	$L_{b_{11}}$	$L_{b_{21}}$	$L_{b_{21}}$	$L_{b_{31}}$	$L_{b_{31}}$	$r\phi_{11}$	$L_{f_{1,14}}$	$L_{f_{2,14}}$
L_t		8	$\frac{L}{k}$									$\frac{L}{k}$		
		32	$\frac{L}{k}$	$\frac{L}{k}$		$L_{t_{11}}$		$L_{t_{21}}$				$\frac{L}{k}$	$\frac{L}{k}$	
		72	$\frac{L}{k}$	$\frac{L}{k}$	$\frac{L}{k}$	$L_{t_{11}}$	$L_{t_{11}}$	$L_{t_{21}}$	$L_{t_{21}}$	$L_{t_{31}}$	$L_{t_{31}}$	$\frac{L}{k}$	$\frac{L}{k}$	$\frac{L}{k}$
L_u		8	$\frac{L}{k}$									$\frac{L}{k}$		
		32	$\frac{L}{k}$	$\frac{L}{k}$		$L_{t_{11}}$		$L_{t_{21}}$				$\frac{L}{k}$	$\frac{L}{k}$	
		72	$\frac{L}{k}$	$\frac{L}{k}$	$\frac{L}{k}$	$L_{t_{11}}$	$L_{t_{11}}$	$L_{t_{21}}$	$L_{t_{21}}$	$L_{t_{31}}$	$L_{t_{31}}$	$\frac{L}{k}$	$\frac{L}{k}$	$\frac{L}{k}$

Table IV[†](Cont'd)

	N	SPHERE AND HEMISPHERICAL END 1,1	2,1	3,1	1,2	1,3	2,2	2,3	3,2	3,3	CYLINDRICAL MIDDLE 1,6; 1,10; 1,14	2,10; 2,14	3,14
α	8	$\frac{1}{2}\theta$									0		
	32	$\frac{1}{2}\theta$	$\frac{1}{2}\theta$		1.5θ		1.5θ				0	0	
	72	$\frac{1}{2}\theta$	$\frac{1}{2}\theta$	$\frac{1}{2}\theta$	1.5θ	2.5θ	1.5θ	2.5θ	1.5θ	2.5θ	0	0	0
b	8	$.707\,\phi_{11}$									$.707\,\phi_{1,1}$		
	32	$.707\,\phi$	$\frac{1}{2}\phi_{2,1}+\phi_{1,1}$		$b_{1,1}$		$b_{2,1}$				$.707\,\phi_{1,1}$	$\frac{1}{2}\phi_{2,1}+\phi_{1,1}$	
	72	$.707\,\phi$	$\frac{1}{2}\phi_{2,1}+\phi_{1,1}$	$\frac{1}{2}\phi_{3,1}+\phi_{2,1}+\phi_{1,1}$	$b_{1,1}$	$b_{1,1}$	$b_{2,1}$	$b_{2,1}$	$b_{3,1}$	$b_{3,1}$	$.707\,\phi_{1,1}$	$\frac{1}{2}\phi_{2,1}+\phi_{1,1}$	$\frac{1}{2}\phi_{3,1}+\phi_{2,1}+\phi_{1,1}$
$\lvert\vec{N}_x\rvert$	8	$\cos b_{1,1}$									$\cos b_{1,1}$		
	32	$\cos b_{1,1}$	$\cos b_{2,1}$		$N_{x_{1,1}}$		$N_{x_{2,1}}$				$\cos b_{1,1}$	$\cos b_{2,1}$	
	72	$\cos b_{1,1}$	$\cos b_{2,1}$	$\cos b_{3,1}$	$N_{x_{1,1}}$	$N_{x_{1,1}}$	$N_{x_{2,1}}$	$N_{x_{2,1}}$	$N_{x_{3,1}}$	$N_{x_{3,1}}$	$\cos b_{1,1}$	$\cos b_{2,1}$	$\cos b_{3,1}$
$\lvert\vec{N}_y\rvert$	8	$\cos a_{1,1}\sin b_{1,1}$									$\cos a_{1,1}\sin b_{1,1}$		
	32	$\cos a_{1,1}\sin b_{1,1}$	$\cos a_{2,1}\sin b_{2,1}$		$\cos a_{1,2}\sin b_{1,2}$		$\cos a_{2,2}\sin b_{2,2}$				$\cos a_{1,1}\sin b_{1,1}$	$\cos a_{2,1}\sin b_{2,1}$	
	72	$\cos a_{1,1}\sin b_{1,1}$	$\cos a_{2,1}\sin b_{2,1}$	$\cos a_{3,1}\sin b_{3,1}$	$\cos a_{1,2}\sin b_{1,2}$	$\cos a_{1,3}\sin b_{1,3}$	$\cos a_{2,2}\sin b_{2,2}$	$\cos a_{2,3}\sin b_{2,3}$	$\cos a_{3,2}\sin b_{3,2}$	$\cos a_{3,3}\sin b_{3,3}$	$\cos a_{1,1}\sin b_{1,1}$	$\cos a_{2,1}\sin b_{2,1}$	$\cos a_{3,1}\sin b_{3,1}$
$\lvert\vec{N}_z\rvert$	8	$\sin a_{1,1}\sin b_{1,1}$									0		
	32	$\sin a_{1,1}\sin b_{1,1}$	$\sin a_{2,1}\sin b_{2,1}$		$\sin a_{1,2}\sin b_{1,2}$		$\sin a_{2,2}\sin b_{2,2}$				0	0	
	72	$\sin a_{1,1}\sin b_{1,1}$	$\sin a_{2,1}\sin b_{2,1}$	$\sin a_{3,1}\sin b_{3,1}$	$\sin a_{1,2}\sin b_{1,2}$	$\sin a_{1,3}\sin b_{1,3}$	$\sin a_{2,2}\sin b_{2,2}$	$\sin a_{2,3}\sin b_{2,3}$	$\sin a_{3,2}\sin b_{3,2}$	$\sin a_{3,3}\sin b_{3,3}$	0	0	0
$\vec{N}$	8	$\pm N_x \pm N_y \pm N_z$									$\pm N_x \pm N_y \pm N_z$		
	32	$\pm N_x \pm N_y \pm N_z$	$\pm N_x \pm N_y \pm N_z$		$\pm N_x \pm N_y \pm N_z$		$\pm N_x \pm N_y \pm N_z$				$\pm N_x \pm N_y \pm N_z$	$\pm N_x \pm N_y \pm N_z$	
	72	$\pm N_x \pm N_y \pm N_z$	$\pm N_x \pm N_y \pm N_z$	$\pm N_x \pm N_y \pm N_z$	$\pm N_x \pm N_y \pm N_z$	$\pm N_x \pm N_y \pm N_z$	$\pm N_x \pm N_y \pm N_z$	$\pm N_x \pm N_y \pm N_z$	$\pm N_x \pm N_y \pm N_z$	$\pm N_x \pm N_y \pm N_z$	$\pm N_x \pm N_y \pm N_z$	$\pm N_x \pm N_y \pm N_z$	$\pm N_x \pm N_y \pm N_z$
a	8	$\sin^{-1}\lvert N_{z_{1,1}}\rvert$											
	32	$\sin^{-1}\lvert N_{z_{1,1}}\rvert$	$\sin^{-1}\lvert N_{z_{2,1}}\rvert$		$\sin^{-1}\lvert N_{z_{1,2}}\rvert$		$\sin^{-1}\lvert N_{z_{2,2}}\rvert$						
	72	$\sin^{-1}\lvert N_{z_{1,1}}\rvert$	$\sin^{-1}\lvert N_{z_{2,1}}\rvert$	$\sin^{-1}\lvert N_{z_{3,1}}\rvert$	$\sin^{-1}\lvert N_{z_{1,2}}\rvert$	$\sin^{-1}\lvert N_{z_{1,3}}\rvert$	$\sin^{-1}\lvert N_{z_{2,2}}\rvert$	$\sin^{-1}\lvert N_{z_{2,3}}\rvert$	$\sin^{-1}\lvert N_{z_{3,2}}\rvert$	$\sin^{-1}\lvert N_{z_{3,3}}\rvert$			
		190 + al	190 − al										
γ	8	n < 3	3 < n < 6 HEMISPHERE	3 < n < 4 SPHERE						γ	90		
	32	n < 5	5 < n < 10	5 < n < 8							90	90	
	72	n < 7	7 < n < 14	7 < n < 12							90	90	90

Table IV† (Cont'd)

	N	SPHERE AND HEMISPHERICAL END									CYLINDRICAL MIDDLE		
		1,1	2,1	3,1	1,2	1,3	2,2	2,3	3,2	3,3	1,6; 1,10; 1,14	2,10; 2,14	3,14
V	8	$\frac{4\pi}{3Nk}[r^3-(r-L)^3]$									$\frac{h\phi_{11}}{2k}[r^2-(r-L)^2]$		
	32	$\frac{4\pi}{3Nk}[r^3-(r-L)^3]$	$\frac{4\pi}{3Nk}[r^3-(r-L)^3]$		V_{11}		V_{21}				$\frac{h\phi_{11}}{2k}[r^2-(r-L)^2]$	$\frac{h\phi_{21}}{2k}[r^2-(r-L)^2]$	
	72	$\frac{4\pi}{3Nk}[r^3-(r-L)^3]$	$\frac{4\pi}{3Nk}[r^3-(r-L)^3]$	$\frac{4\pi}{3Nk}[r^3-(r-L)^3]$	V_{11}	V_{11}	V_{21}	V_{21}	V_{31}	V_{31}	$\frac{h\phi_{11}}{2k}[r^2-(r-L)^2]$	$\frac{h\phi_{21}}{2k}[r^2-(r-L)^2]$	$\frac{h\phi_{31}}{2k}\, r^2-(r-L)^2]$

	N	N_x	N_y	N_z
+ OR −	8	+, M ≤ 1	−, 2 ≤ N ≤ 4 $\boxed{\le 3}$	+, 1 ≤ N ≤ 2
	32	+, M ≤ 2	−, 3 ≤ N ≤ 7 $\boxed{\le 6}$	+, 1 ≤ N ≤ 4
	72	+, M ≤ 3	−, 4 ≤ N ≤ 10 $\boxed{\le 9}$	+, 1 ≤ N ≤ 6
Φ	8	$\frac{N}{\pi}\sin^2(\phi_B/2)\sin\frac{\theta}{2}\cos\frac{\theta}{2}$		
	32	$\frac{N}{\pi}\sin^2(\phi_B/2)\sin\frac{\theta}{2}\cos\frac{\theta}{2}$		
	72	$\frac{N}{\pi}\sin^2(\phi_B/2)\sin\frac{\theta}{2}\cos\frac{\theta}{2}$		

$\square$ SPHERE ONLY

† SPHERE (CODE NUMBER 0) AND CYLINDRICAL MIDDLE WITH HEMISPHERICAL ENDS (CODE NUMBER -1.0)

Table IV†† (Cont'd)

	N	FLAT END	CYLINDRICAL MIDDLE
ϕ	8	$4\pi/N$	$4\pi/N$
	16	$4\pi/N$	$4\pi/N$
	24	$4\pi/N$	$4\pi/N$
A_l	8	0	$r\phi_u L/k$
	16	0	$r\phi_u L/k$
	24	0	$r\phi_u L/k$
A_r	8	$r\phi_u L/k$	$r\phi_u L/k$
	16	$r\phi_u L/k$	$r\phi_u L/k$
	24	$r\phi_u L/k$	$r\phi_u L/k$
A_f	8	rL/k	$\frac{hL}{k}$
	16	rL/k	$\frac{hL}{k}$
	24	rL/k	$\frac{hL}{k}$
A_b	8	rL/k	$\frac{hL}{k}$
	16	rL/k	$\frac{hL}{k}$
	24	rL/k	$\frac{hL}{k}$
A_t	8	$2\pi r^2/N$	$r\phi_u h$
	16	$2\pi r^2/N$	$r\phi_u h$
	24	$2\pi r^2/N$	$r\phi_u h$
A_u	8	$2\pi r^2/N$	$r\phi_u h$
	16	$2\pi r^2/N$	$r\phi_u h$
	24	$2\pi r^2/N$	$r\phi_u h$
$\bar{A}_t$	8	$2\pi r^2/N$	$2r \sin(\phi_u/2)\cdot h$
	16	$2\pi r^2/N$	$2r \sin(\phi_u/2)\cdot h$
	24	$2\pi r^2/N$	$2r \sin(\phi_u/2)\cdot h$
l_l	8	$\frac{2}{3}r$	$\frac{h}{2}+\frac{1}{3}r$
	16	$\frac{2}{3}r$	$\frac{h}{2}+\frac{1}{3}r$
	24	$\frac{2}{3}r$	$\frac{h}{2}+\frac{1}{3}r$
l_r	8	$\frac{h}{2}+\frac{1}{3}r$	$\frac{h}{2}+\frac{1}{3}r$
	16	$\frac{h}{2}+\frac{1}{3}r$	$\frac{h}{2}+\frac{1}{3}r$
	24	$\frac{h}{2}+\frac{1}{3}r$	$\frac{h}{2}+\frac{1}{3}r$
l_f	8	$8\pi r/3N$	$r\phi_{1,1}$
	16	$8\pi r/3N$	$r\phi_u$
	24	$8\pi r/3N$	$r\phi_u$
l_b	8	$8\pi r/3N$	$r\phi_u$
	16	$8\pi r/3N$	$r\phi_u$
	24	$8\pi r/3N$	$r\phi_u$

	N	FLAT END		CYLINDRICAL MIDDLE
l_t	8	L/k		L/k
	16	L/k		L/k
	24	L/k		L/k
l_u	8	L/k		L/k
	16	L/k		L/k
	24	L/k		L/k
α	8	90°		0
	16	90°		0
	24	90°		0
b	8			$1/2\phi_{1,1}$
	16			$1/2\phi_{1,1}$
	24			$1/2\phi_{1,1}$
$\lvert\vec{N}_x\rvert$	8			$\cos b_{1,1}$
	16			$\cos b_{1,1}$
	24			$\cos b_{1,1}$
$\lvert\vec{N}_y\rvert$	8			$\sin b_{1,1}$
	16			$\sin b_{1,1}$
	24			$\sin b_{1,1}$
$\lvert\vec{N}_z\rvert$	8	1.0		0
	16	1.0		0
	24	1.0		0
$\vec{N}$	8	1.0		$\pm N_x \pm N_y$
	16	1.0		$\pm N_x \pm N_y$
	24	1.0		$\pm N_x \pm N_y$
γ	8	180°	0°	90°
	16	180°	0°	90°
	24	180°	0°	90°
	ELEMENTS	1,1; 2,1; 3,1; 4,1; 5,1; 6,1 1,2; 2,2; 3,2; 4,2; 5,2; 6,2	1,5; 2,5; 3,5; 4,5; 6,5; 5,5 1,4; 2,4; 3,4; 4,4 5,4; 6,4	
+	N_x			+, $m \leq \frac{N}{8}$
or	N_y			−, $2 \leq n \leq 4$
−	N_z	+, $n \leq 2$		
V	8	$A_t L/k$		$\frac{2\pi h}{N_k}\left[r^2-(r-L)^2\right]$
	16	$A_t L/k$		$\frac{2\pi h}{N_k}\left[r^2-(r-L)^2\right]$
	24	$A_t L/k$		$\frac{2\pi h}{N_k}\left[r^2-(r-L)^2\right]$

†† CYLINDER WITH FLAT ENDS (CODE NUMBER IS + 1.0)

Table V

This table indicates the symmetry of the elements. All elements within a given block (one of the small blocks) have equal values for the quantities listed in the heading. For example, the numerical value of ϕ for all elements in the first block (1, 1; 1, 6; 1, 13; 1, 8; etc.) is the same and need be computed only once.

SPHERE AND HEMISPHERICAL END								CYLINDRICAL MIDDLE			
N = 72											
$\phi, A_L, A_r, A_f, A_b, A_t, A_u$ $L_L, L_r, L_f, L_b, L_t, L_u$ $\bar{N}_x, \bar{N}_y, \bar{N}_z, a, b, \alpha$				HEMISPHERICAL END ONLY				$\phi, A_L, A_r, A_f, A_t, A_t, A_u$ $L_L, L_r, L_f, L_b, L_t, L_u$			
				L_L	L_r		L_L				
1,1	1,6	1,13	1,8	1,1	1,6	1,13	1,8	1,14	1,7	6,14	6,7
6,1	6,6	6,13	6,8	6,1	6,6	6,13	6,8				
2,1	2,6	2,13	2,8	2,1	2,6	2,13	2,8	2,14	2,7	5,14	5,7
5,1	5,6	5,13	5,8	5,1	5,6	5,13	5,8				
3,1	3,6	3,13	3,8	3,1	3,6	3,13	3,8	3,14	3,7	4,14	4,7
4,1	4,6	4,13	4,8	4,1	4,6	4,13	4,8				
1,2	1,5	1,12	1,9								
6,2	6,5	6,12	6,9								
2,2	2,5	2,12	2,9								
5,2	5,5	5,12	5,9								
3,2	3,5	3,12	3,9								
4,2	4,5	4,12	4,9								
1,3	1,4	1,11	1,10								
6,3	6,4	6,11	6,10								
2,3	2,4	2,11	2,10								
5,3	5,4	5,11	5,10								
3,3	3,4	3,11	3,10								
4,3	4,4	4,11	4,10								
N = 32											
1,1	1,4	1,9	1,6	1,1	1,4	1,9	1,6	1,10	1,5	4,10	4,5
4,1	4,4	4,6	4,9	4,1	4,4	4,9	4,6				
2,1	2,4	2,6	2,9	2,1	2,4	2,9	2,6	2,10	2,5	3,10	3,5
3,1	3,4	3,6	3,9	3,1	3,4	3,9	3,6				
1,2	1,3	1,7	1,8								
4,2	4,3	4,7	4,8								
2,2	2,3	2,7	2,8								
3,2	3,3	3,7	3,8								
N = 8											
1,1	1,2	1,5	1,4	1,1	1,2	1,5	1,4	1,6	1,3	2,6	2,3
2,1	2,2	2,5	2,4	2,1	2,2	2,5	2,4				
				1,2	1,1	1,4	1,5				
				2,2	2,1	2,4	2,5				

COMPUTER PROGRAM-DECK SETUP INSTRUCTIONS

All the data for one run is punched sequentially, as it appears in title (input data), on one tabulating card.

JJ ≡ is an added location that must contain a zero for the last in a stack of runs, otherwise a nonzero number.

FIG ≡ is an added location that must contain a 0.0 for a sphere, A+1.0 for a flat end cylinder, or A-1.0 for a cylinder with hemispherical ends.

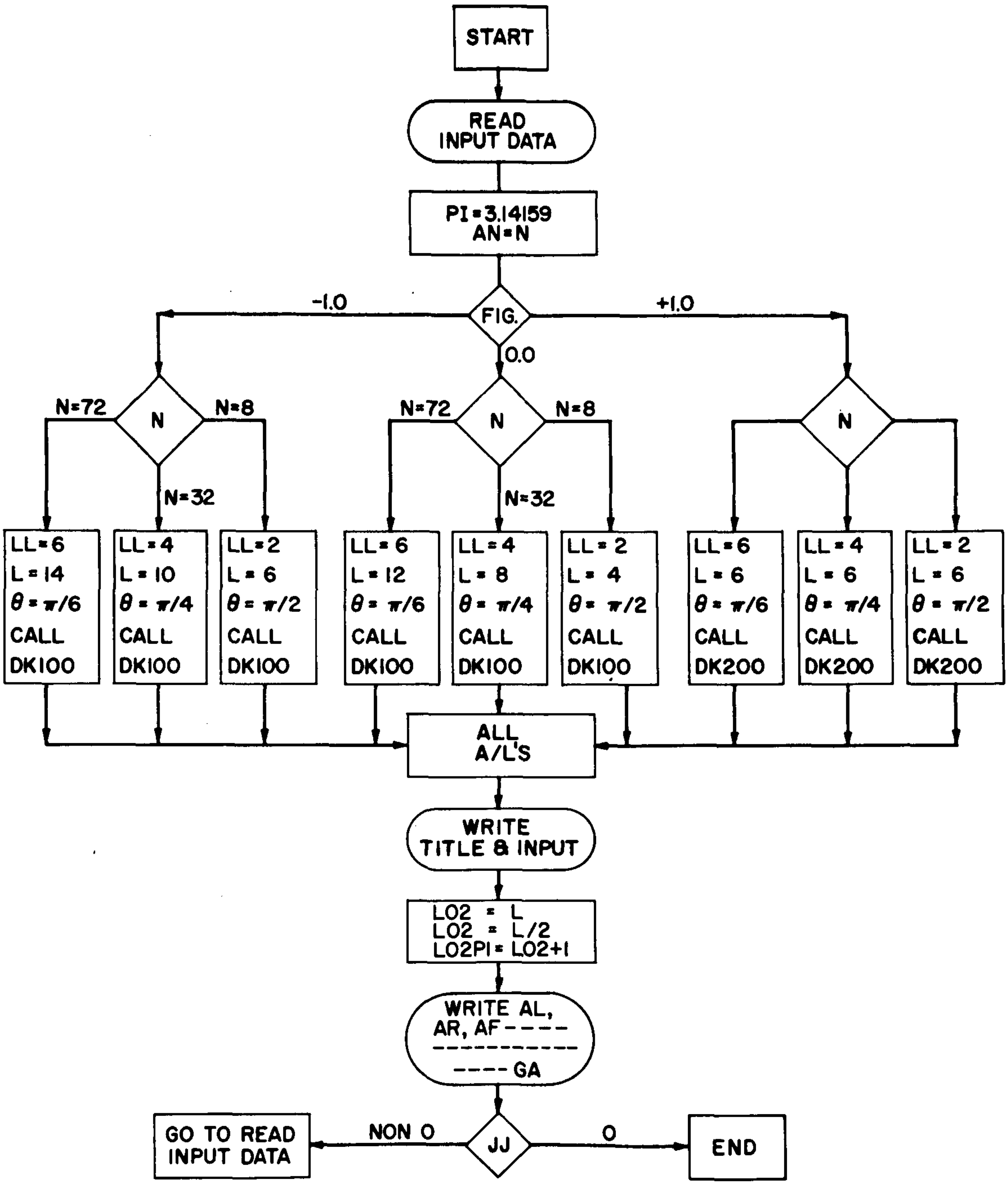
The read statement is: 2 READ(5,3) N, JJ, FIG. A, H, R, B

The format statement is: 3FORMAT(2I5, 5F10.0)

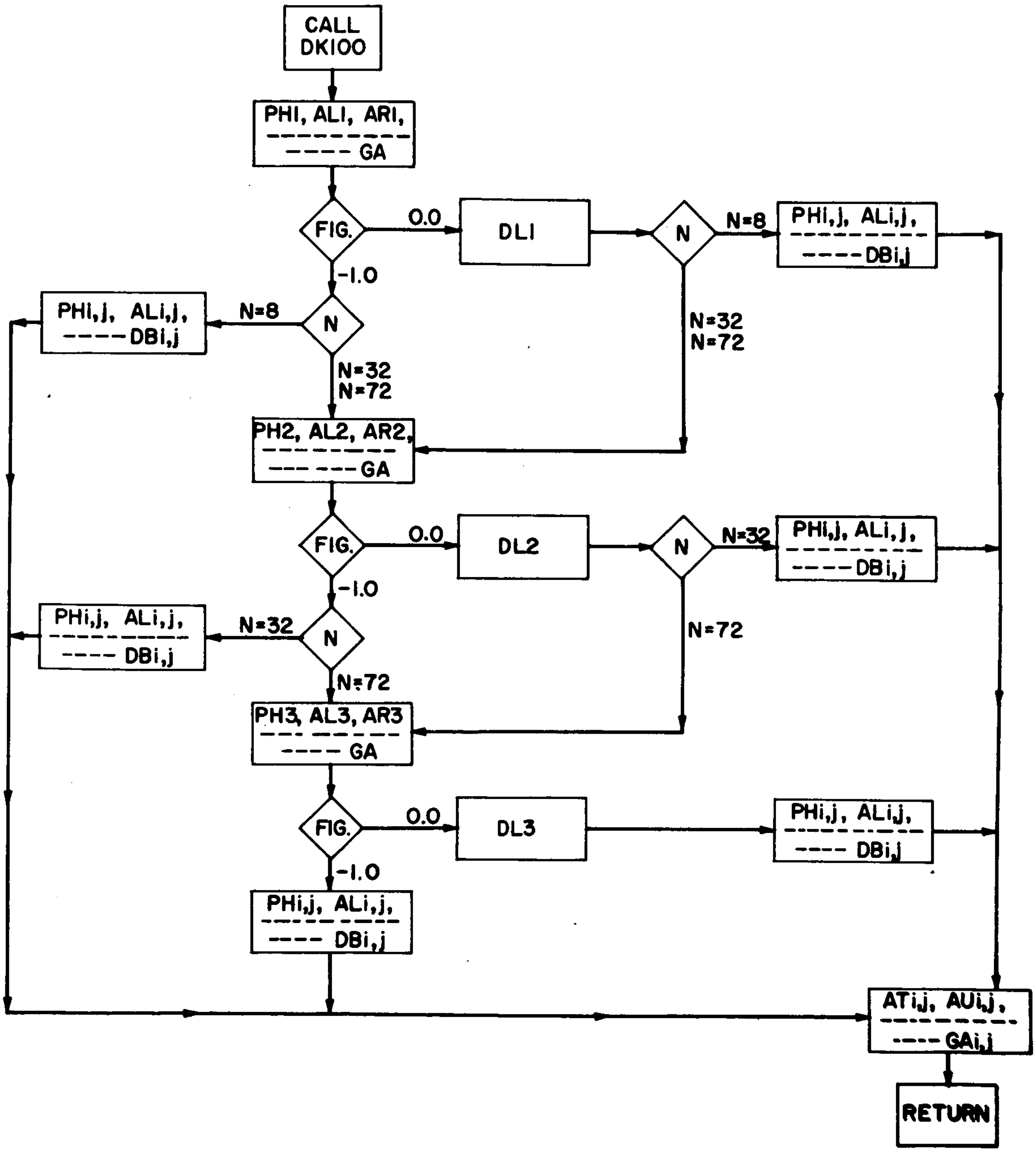
TABULATING CARD

```
1-------5-------10------ 20-------30-------40-------50-------60
    N       JJ      FIG       A        H         R         B
```

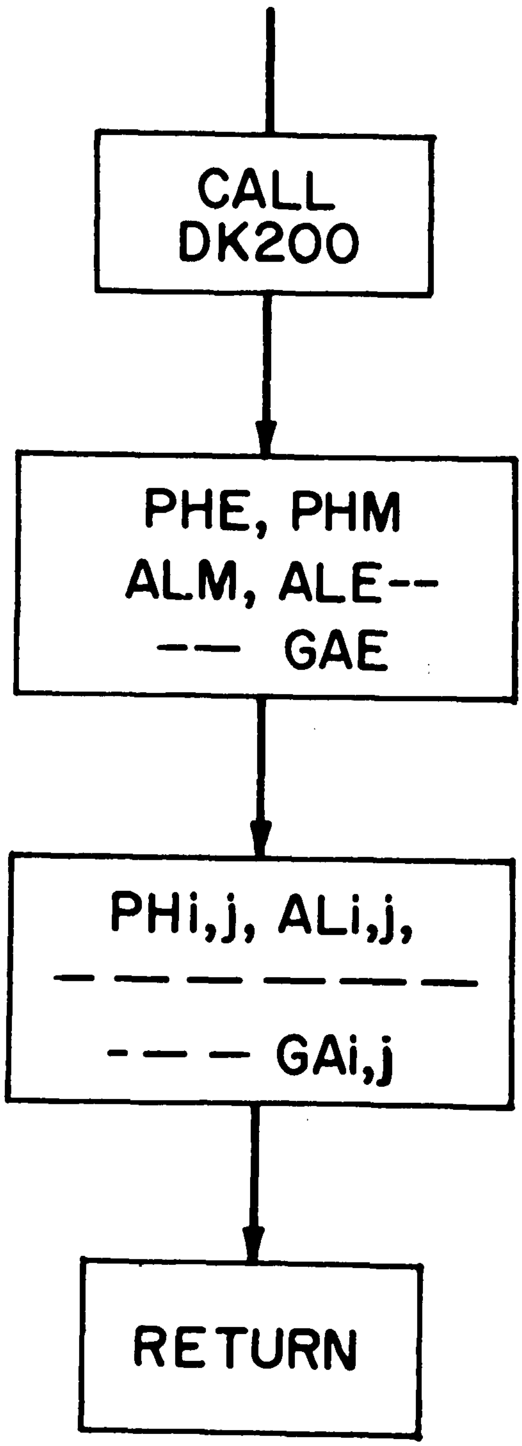
MAIN PROGRAM FLOW CHART



SUBROUTINE DK100



SUBROUTINE DK200



MAIN PROGRAM

LISTING

```
      CØMMØN AT(6,14),AU(6,14),AL(6,14),AR(6,14),AF(6,14),AB(6,14),ATB(6
     C,14),ALP(6,14),A1(6,14),B1(6,14),DT(6,14),DU(6,14),DB(6,14),DF(6,1
     C4),DR(6,14),DL(6,14),GA(6,14),PH(6,14),V(6,14),VX(6,14),VY(6,14),V
     CZ(6,14),AØDL(6,14),AØDR(6,14),AØDF(6,14),AØDB(6,14),AØDT(6,14),AØD
     CU(6,14),VØL(6,14),NE(14),N,FIG,A,B,H,R
    2 READ(5,3)N,JJ,FIG,A,H,R,B
    3 FØRMAT(2I5,5F10.0)
      PI=3.14159
      AN=N
      IF(FIG)145,115,116
  116 IF(N-16)117,118,119
  117 LL=2
      L=6
      TH=PI/2.0
      CALL DK200(AN,LL,L,TH)
      GØ TØ 875
  118 LL=4
      L=6
      TH=PI/4.0
      CALL DK200(AN,LL,L,TH)
      GØ TØ 875
  119 LL=6
      L=6
      TH=PI/6.0
      CALL DK200(AN,LL,L,TH)
      GØ TØ 875
  115 IF(N-32)146,147,148
  146 LL=2
      L=4
      TH=PI/2.0
      CALL DK100(AN,LL,L,TH)
      GØ TØ 875
  147 LL=4
      L=8
      TH=PI/4.0
      CALL DK100(AN,LL,L,TH)
      GØ TØ 875
  148 LL=6
      L=12
      TH=PI/6.0
      CALL DK100(AN,LL,L,TH)
      GØ TØ 875
  145 IF(N-32)6,7,8
    6 L=6
      LL=2
      TH=PI/2.0
      CALL DK100(AN,LL,L,TH)
      GØ TØ 875
    7 L=10
      LL=4
      TH=PI/4.0
      CALL DK100(AN,LL,L,TH)
      GØ TØ 875
    8 L=14
      LL=6
```

```
      TH=PI/6.0
      CALL DK100(AN,LL,L,TH)
  875 DØ 200 I=1,LL
      DØ 200 J=1,L
      AØDL(I,J)=AL(I,J)/DL(I,J)
      AØDR(I,J)=AR(I,J)/DR(I,J)
      AØDF(I,J)=AF(I,J)/DF(I,J)
      AØDB(I,J)=AB(I,J)/DB(I,J)
      AØDT(I,J)=AT(I,J)/DT(I,J)
      AØDU(I,J)=AU(I,J)/DU(I,J)
  200 CØNTINUE
      WRITE(6,880)N,A,H,R,B,TH,FIG
  880 FØRMAT(1H1,46X,37H*** CRYØGENIC STØRAGE ØN THE MØØN ***////56X,3H
     C N=I3/56X,3H L=E14.5/56X,3H H=E14.5/56X,3H R=E14.5/56X,3H K=E14.5/
     C53X,6HTHETA=E14.5//30X,44HIF CØDE NUMBER = 0.0 THE FIGURE IS A SPH
     CERE,/30X,61HIF CØDE NUMBER = 1.0 THE FIGURE IS A CYLINDER WITH FLA
     CT ENDS,/30X,70HIF CØDE NUMBER =-1.0 THE FIGURE IS A CYLINDER WITH
     CHEMISPHERICAL ENDS.//57X,13HCØDE NUMBER =F5.1)
      NA=0
      DØ 871 J=1,L
      NA=NA+1
  871 NE(J)=NA
      IF(L-8)800,800,801
  800 LØ2=L
      GØ TØ 802
  801 LØ2=L/2
      LØ2P1=LØ2+1
  802 WRITE(6,803)(NE(J),J=1,LØ2)
  803 FØRMAT(///7X,20HPHI ANGLE IN RADIANS//(3X,8I14))
      DØ 804 I=1,LL
  804 WRITE(6,805)I,(PH(I,J),J=1,LØ2)

  805 FØRMAT(6X,I3,8E14.5)
      IF(L-8)806,806,807
  807 WRITE(6,808)(NE(J),J=LØ2P1,L)
  808 FØRMAT(/3X,8I14)
      DØ 809 I=1,LL
  809 WRITE(6,805)I,(PH(I,J),J=LØ2P1,L)

  806 WRITE(6,810)(NE(J),J=1,LØ2)
  810 FØRMAT(///7X,9HAREA LEFT//(3X,8I14))
      DØ 811 I=1,LL
  811 WRITE(6,805)I,(AL(I,J),J=1,LØ2)

      IF(L-8)812,812,813
  813 WRITE(6,808)(NE(J),J=LØ2P1,L)
      DØ 814 I=1,LL
  814 WRITE(6,805)I,(AL(I,J),J=LØ2P1,L)

  812 WRITE(6,815)(NE(J),J=1,LØ2)
  815 FØRMAT(///7X,10HAREA RIGHT//(3X,8I14))
      DØ 816 I=1,LL
  816 WRITE(6,805)I,(AR(I,J),J=1,LØ2)

      IF(L-8)817,817,818
  818 WRITE(6,808)(NE(J),J=LØ2P1,L)
```

```
      DØ 819 I=1,LL
  819 WRITE(6,805)I,(AR(I,J),J=LØ2P1,L)

  817 WRITE(6,820)(NE(J),J=1,LØ2)
  820 FØRMAT(///7X,10HAREA FRØNT//(3X,8I14))
      DØ 821 I=1,LL
  821 WRITE(6,805)I,(AF(I,J),J=1,LØ2)

      IF(L-8)822,822,823
  823 WRITE(6,808)(NE(J),J=LØ2P1,L)
      DØ 824 I=1,LL
  824 WRITE(6,805)I,(AF(I,J),J=LØ2P1,L)

  822 WRITE(6,825)(NE(J),J=1,LØ2)
  825 FØRMAT(///7X,9HAREA BACK//(3X,8I14))
      DØ 826 I=1,LL
  826 WRITE(6,805)I,(AB(I,J),J=1,LØ2)

      IF(L-8)827,827,828
  828 WRITE(6,808)(NE(J),J=LØ2P1,L)
      DØ 829 I=1,LL
  829 WRITE(6,805)I,(AB(I,J),J=LØ2P1,L)

  827 WRITE(6,830)(NE(J),J=1,LØ2)
  830 FØRMAT(///7X,8HAREA TØP//(3X,8I14))
      DØ 831 I=1,LL
  831 WRITE(6,805)I,(AT(I,J),J=1,LØ2)

      IF(L-8)833,833,834
  834 WRITE(6,808)(NE(J),J=LØ2P1,L)
      DØ 835 I=1,LL
  835 WRITE(6,805)I,(AT(I,J),J=LØ2P1,L)

  833 WRITE(6,836)(NE(J),J=1,LØ2)
  836 FØRMAT(///7X,10HAREA UNDER//(3X,8I14))
      DØ 837 I=1,LL
  837 WRITE(6,805)I,(AU(I,J),J=1,LØ2)

      IF(L-8)838,838,839
  839 WRITE(6,808)(NE(J),J=LØ2P1,L)
      DØ 840 I=1,LL
  840 WRITE(6,805)I,(AU(I,J),J=LØ2P1,L)

  838 WRITE(6,841)(NE(J),J=1,LØ2)
  841 FØRMAT(///7X,14HAREA BAR SUB T//(3X,8I14))
      DØ 842 I=1,LL
  842 WRITE(6,805)I,(ATB(I,J),J=1,LØ2)

      IF(L-8)843,843,844
  844 WRITE(6,808)(NE(J),J=LØ2P1,L)
      DØ 845 I=1,LL
  845 WRITE(6,805)I,(ATB(I,J),J=LØ2P1,L)

  843 WRITE(6,846)(NE(J),J=1,LØ2)
  846 FØRMAT(///7X,11HLENGTH LEFT//(3X,8I14))
      DØ 847 I=1,LL
```

```
847 WRITE(6,805)I,(DL(I,J),J=1,LØ2)

    IF(L-8)848,848,849
849 WRITE(6,808)(NE(J),J=LØ2P1,L)
    DØ 850 I=1,LL
850 WRITE(6,805)I,(DL(I,J),J=LØ2P1,L)

848 WRITE(6,851)(NE(J),J=1,LØ2)
851 FØRMAT(///7X,12HLENGTH RIGHT//(3X,8I14))
    DØ 852 I=1,LL
852 WRITE(6,805)I,(DR(I,J),J=1,LØ2)

    IF(L-8)853,853,854
854 WRITE(6,808)(NE(J),J=LØ2P1,L)
    DØ 855 I=1,LL
855 WRITE(6,805)I,(DR(I,J),J=LØ2P1,L)

853 WRITE(6,856)(NE(J),J=1,LØ2)
856 FØRMAT(///7X,12HLENGTH FRØNT//(3X,8I14))
    DØ 857 I=1,LL
857 WRITE(6,805)I,(DF(I,J),J=1,LØ2)

    IF(L-8)858,858,859
859 WRITE(6,808)(NE(J),J=LØ2P1,L)
    DØ 860 I=1,LL
860 WRITE(6,805)I,(DF(I,J),J=LØ2P1,L)

858 WRITE(6,861)(NE(J),J=1,LØ2)
861 FØRMAT(///7X,11HLENGTH BACK//(3X,8I14))
    DØ 862 I=1,LL
862 WRITE(6,805)I,(DB(I,J),J=1,LØ2)

    IF(L-8)863,863,864
864 WRITE(6,808)(NE(J),J=LØ2P1,L)
    DØ 865 I=1,LL
865 WRITE(6,805)I,(DB(I,J),J=LØ2P1,L)

863 WRITE(6,866)(NE(J),J=1,LØ2)
866 FØRMAT(///7X,10HLENGTH TØP//(3X,8I14))
    DØ 367 I=1,LL
367 WRITE(6,805)I,(DT(I,J),J=1,LØ2)

    IF(L-8)867,867,868
868 WRITE(6,808)(NE(J),J=LØ2P1,L)
    DØ 371 I=1,LL
371 WRITE(6,805)I,(DT(I,J),J=LØ2P1,L)

867 WRITE(6,372)(NE(J),J=1,LØ2)
372 FØRMAT(///7X,12HLENGTH UNDER//(3X,8I14))
    DØ 373 I=1,LL
373 WRITE(6,805)I,(DU(I,J),J=1,LØ2)

    IF(L-8)374,374,375
375 WRITE(6,808)(NE(J),J=LØ2P1,L)
    DØ 876 I=1,LL
876 WRITE(6,805)I,(DU(I,J),J=LØ2P1,L)
```

```
374 WRITE(6,877)(NE(J),J=1,LØ2)
877 FØRMAT(///7X,22HANGLE ALPHA IN RADIANS//(3X,8I14))
    DØ 878 I=1,LL
878 WRITE(6,805)I,(ALP(I,J),J=1,LØ2)
    IF(L-8)879,879,380
380 WRITE(6,808)(NE(J),J=LØ2P1,L)
    DØ 881 I=1,LL
881 WRITE(6,805)I,(ALP(I,J),J=LØ2P1,L)
879 WRITE(6,882)(NE(J),J=1,LØ2)
882 FØRMAT(///7X,7HSMALL A//(3X,8I14))
    DØ 883 I=1,LL
883 WRITE(6,805)I,(A1(I,J),J=1,LØ2)
    IF(L-8)884,884,885
885 WRITE(6,808)(NE(J),J=LØ2P1,L)
    DØ 886 I=1,LL
886 WRITE(6,805)I,(A1(I,J),J=LØ2P1,L)
884 WRITE(6,887)(NE(J),J=1,LØ2)
887 FØRMAT(///7X,7HSMALL B//(3X,8I14))
    DØ 888 I=1,LL
888 WRITE(6,805)I,(B1(I,J),J=1,LØ2)
    IF(L-8)889,889,890
890 WRITE(6,808)(NE(J),J=LØ2P1,L)
    DØ 891 I=1,LL
891 WRITE(6,805)I,(B1(I,J),J=LØ2P1,L)
889 WRITE(6,892)(NE(J),J=1,LØ2)
892 FØRMAT(///7X,9HVECTØR NX//(3X,8I14))
    DØ 893 I=1,LL
893 WRITE(6,805)I,(VX(I,J),J=1,LØ2)
    IF(L-8)894,894,895
895 WRITE(6,808)(NE(J),J=LØ2P1,L)
    DØ 896 I=1,LL
896 WRITE(6,805)I,(VX(I,J),J=LØ2P1,L)
894 WRITE(6,897)(NE(J),J=1,LØ2)
897 FØRMAT(///7X,9HVECTØR NY//(3X,8I14))
    DØ 898 I=1,LL
898 WRITE(6,805)I,(VY(I,J),J=1,LØ2)
    IF(L-8)899,899,920
920 WRITE(6,808)(NE(J),J=LØ2P1,L)
    DØ 921 I=1,LL
921 WRITE(6,805)I,(VY(I,J),J=LØ2P1,L)
899 WRITE(6,922)(NE(J),J=1,LØ2)
922 FØRMAT(///7X,9HVECTØR NZ//(3X,8I14))
    DØ 923 I=1,LL
923 WRITE(6,805)I,(VZ(I,J),J=1,LØ2)
```

```
      IF(L-8)924,924,925
925   WRITE(6,808)(NE(J),J=LØ2P1,L)
      DØ 926 I=1,LL
926   WRITE(6,805)I,(VZ(I,J),J=LØ2P1,L)

924   WRITE(6,206)(NE(J),J=1,LØ2)
206   FØRMAT(////7X,14HTØTAL VECTØR N//(3X,8I14))
      DØ 201 I=1,LL
201   WRITE(6,805)I,(V(I,J),J=1,LØ2)

      IF(L-8)203,203,204
204   WRITE(6,808)(NE(J),J=LØ2P1,L)
      DØ 205 I=1,LL
205   WRITE(6,805)I,(V(I,J),J=LØ2P1,L)

203   WRITE(6,927)(NE(J),J=1,LØ2)
927   FØRMAT(////7X,22HANGLE GAMMA IN RADIANS//(3X,8I14))
      DØ 928 I=1,LL
928   WRITE(6,805)I,(GA(I,J),J=1,LØ2)

      IF(L-8)773,773,929
929   WRITE(6,808)(NE(J),J=LØ2P1,L)
      DØ 930 I=1,LL
930   WRITE(6,805)I,(GA(I,J),J=LØ2P1,L)

773   WRITE(6,774)(NE(J),J=1,LØ2)
774   FØRMAT(////7X,22HVØLUME ØF EACH ELEMENT//(3X,8I14))
      DØ 775 I=1,LL
775   WRITE(6,805)I,(VØL(I,J),J=1,LØ2)

      IF(L-8)869,869,776
776   WRITE(6,808)(NE(J),J=LØ2P1,L)
      DØ 777 I=1,LL
777   WRITE(6,805)I,(VØL(I,J),J=LØ2P1,L)

869   IF(JJ)2,29,2
 29   STØP
      END
```

```
      SUBRØUTINE DK100(AN,LL,L,TH)
      CØMMØN AT(6,14),AU(6,14),AL(6,14),AR(6,14),AF(6,14),AB(6,14),ATB(6
     C,14),ALP(6,14),A1(6,14),B1(6,14),DT(6,14),DU(6,14),DB(6,14),DF(6,1
     C4),DR(6,14),DL(6,14),GA(6,14),PH(6,14),V(6,14),VX(6,14),VY(6,14),V
     CZ(6,14),AØDL(6,14),AØDR(6,14),AØDF(6,14),AØDB(6,14),AØDT(6,14),AØD
     CU(6,14),VØL(6,14),NE(14),N,FIG,A,B,H,R
      PI=3.14159
    9 THØ2=TH/2.0
      CIS=1.0-((4.0*PI)/(AN*TH))
      PH1=ARKCØS(CIS,IERR)
      PH1Ø2=PH1/2.0
      SIP1=SIN(PH1Ø2)
      SIP1SQ=SIP1**2
      SITH=SIN(THØ2)
      CØTH=CØS(THØ2)
      CPH=(AN/PI)*SIP1SQ*SITH*CØTH
      IF(IERR)4,5,4
    4 WRITE(6,28)
   28 FØRMAT(///10X,15HERRØR IN ARKCØS)
    5 AL1=(R*PH1*A/B)*(1.0-(A/(2.*R*B)))
      AR1=AL1
      SP1=SIN(PH1)
      AF1=((R*A*TH)/B)*(SP1-A/(2.*B*R))
      AB1=0.0
      AT1=(4.*PI*R**2)/AN
      AU1=AT1
      DL1=(H/2.)+(R*TH/4.)*SP1
      DR1=(R*TH/2.)*SP1
      DF1=R*PH1
      DB1=(R/2.)*PH1
      DT1=A/B
      DU1=DT1
      VØL1=(4.0/(3.*AN*B))*PI*(R**3-(R-A)**3)
      B11=0.707*PH1
      ALP1=0.5*TH
      SN1=SIN(B11)
      VZ11=SIN(ALP1)*SN1
      VY11=CØS(ALP1)*SN1
      A11=ARKSIN(ABS(VZ11),IERR)
      IF(IERR)4,150,4
  150 VX1=CØS(B11)
      AVX1=ABS(VX1)
      AVY11=ABS(VY11)
      AVZ11=ABS(VZ11)
      AT1L=R*PH1*H
      AU1L=AT1L
      ATB1L=2.*R*H*SIN(PH1/2.)
      AL1L=((R*PH1*A)/B)*(1.-(A/(2.*B*R)))
      AR1L=AL1L
      AF1L=A*H/B
      AB1L=AF1L
      ATB1=CPH*AT1
      DL1L=(H/2.)+(R*TH/4.)*SP1
      DR1L=DL1L
      DF1L=R*PH1
```

```
      DB1L=DF1L
      VØL1L=(PH1/(2.*B))*H*(R**2-(R-A)**2)
      IF(FIG)166,167,167
  166 IF(N-32)10,11,11
   10 DØ 30 I=1,2
      DØ 30 J=1,6
   30 PH(I,J)=PH1
      DØ 31 I=1,2
      DØ 31 J=1,5
      IF(J-3)32,31,32
   32 AL(I,J)=AL1
      AR(I,J)=AR1
      AF(I,J)=AF1
      AB(I,J)=AB1
      DF(I,J)=DF1
      DB(I,J)=DB1
      B1(I,J)=B11
   31 CØNTINUE
      DØ 70 I=1,2
      DØ 70 J=1,5
      IF(J-2)71,72,73
   73 IF(J-3)70,70,74
   74 IF(J-4)71,71,72
   71 DL(I,J)=DL1
      DR(I,J)=DR1
      GØ TØ 70
   72 DL(I,J)=DR1
      DR(I,J)=DL1
   70 CØNTINUE
      DØ 33 I=1,2
      DØ 33 J=3,6
      IF(J-4)34,35,35
   35 IF(J-5)33,33,34
   34 AT(I,J)=AT1L
      AU(I,J)=AU1L
      ATB(I,J)=ATB1L
      AL(I,J)=AL1L
      AR(I,J)=AR1L
      AF(I,J)=AF1L
      AB(I,J)=AB1L
      DF(I,J)=DF1L
      DB(I,J)=DB1L
      B1(I,J)=B11
   33 CØNTINUE
      GØ TØ 873
  167 DL1=(R*TH/2.0)*SIN(PH1)
      IF(N-32)168,11,11
  168 DØ 169 I=1,LL
      DØ 169 J=1,L
      PH(I,J)=PH1
      AL(I,J)=AL1
      AR(I,J)=AR1
      AF(I,J)=AF1
      AB(I,J)=AB1
      DL(I,J)=DL1
      DR(I,J)=DR1
```

```
      DF(I,J)=DF1
      DB(I,J)=DB1
      BI(I,J)=BI1
  169 CØNTINUE
      GØ TØ 874
   11 CØS1=(1.0-((8.*PI)/(AN*TH)))
      PH2=ARKCØS(CØS1,IERR)-PH1
      IF(IERR)4,19,4
   19 AL2=(R*PH2*A/B)*(1.0-(A/(2.*B*R)))
      AR2=AL2
      SP2=SIN(PH1+PH2)
      AF2=((A*R*TH)/B)*(SP2-(A/(2.*B*R)))
      AB2=AF1
      DL2=(H/2.)+(R*TH/4.0)*(SP1+SP2)
      DR2=(R*TH/2.)*(SP1+SP2)
      DF1=(R/2.0)*(PH1+PH2)
      DF2=R*PH2
      DB2=DF1
      AT2L=R*PH2*H
      AU2L=AT2L
      ATB2L=2.*R*SIN(PH2/2.)*H
      AL2L=(R*PH2*A/B)*(1.-(A/(2.*B*R)))
      AR2L=AL2L
      AF2L=H*A/B
      AB2L=AF2L
      DL2L=(H/2.)+(R*TH/4.)*(SP1+SP2)
      DR2L=DL2L
      DF1L=DF1
      DF2L=R*PH2
      DB1L=R*PH1
      DB2L=DF1L
      VØL2L=(PH2/(2.*B))*H*(R**2-(R-A)**2)
      B12=0.5*PH2+PH1
      ALP2=1.5*TH
      SN2=SIN(B12)
      VZ21=SIN(ALP1)*SN2
      VZ12=SIN(ALP2)*SN1
      VZ22=SIN(ALP2)*SN2
      VY21=CØS(ALP1)*SN2
      VY12=CØS(ALP2)*SN1
      VY22=CØS(ALP2)*SN2
      A21=ARKSIN(ABS(VZ21),IERR)
      A12=ARKSIN(ABS(VZ12),IERR)
      A22=ARKSIN(ABS(VZ22),IERR)
      IF(IERR)4,12,4
   12 VX2=CØS(B12)
      AVX2=ABS(VX2)
      AVY21=ABS(VY21)
      AVY12=ABS(VY12)
      AVY22=ABS(VY22)
      AVZ12=ABS(VZ12)
      AVZ21=ABS(VZ21)
      AVZ22=ABS(VZ22)
      IF(FIG)187,188,188
  187 IF(N-32)20,20,21
   20 DØ 36 I=1,4
```

```
      DØ 36 J=1,9
      IF(I-2)37,38,38
   38 IF(I-3)39,39,37
   37 IF(J-5)40,36,40
   40 PH(I,J)=PH1
      AL(I,J)=AL1
      AR(I,J)=AR1
      AF(I,J)=AF1
      AB(I,J)=AB1
      DF(I,J)=DF1
      DB(I,J)=DB1
      B1(I,J)=B11
      GØ TØ 36
   39 IF(J-5)41,36,41
   41 PH(I,J)=PH2
      AL(I,J)=AL2
      AR(I,J)=AR2
      AF(I,J)=AF2
      AB(I,J)=AB2
      DF(I,J)=DF2
      DB(I,J)=DB2
      B1(I,J)=B12
   36 CØNTINUE
      DØ 42 I=1,4
      DØ 42 J=5,10,5
      IF(I-2)43,45,44
   44 IF(I-3)45,45,43
   43 PH(I,J)=PH1
      AT(I,J)=AT1L
      AU(I,J)=AU1L
      ATB(I,J)=ATB1L
      AL(I,J)=AL1L
      AR(I,J)=AR1L
      AF(I,J)=AF1L
      AB(I,J)=AB1L
      DF(I,J)=DF1L
      DB(I,J)=DB1L
      B1(I,J)=B11
      GØ TØ 42
   45 PH(I,J)=PH2
      AT(I,J)=AT2L
      AU(I,J)=AU2L
      ATB(I,J)=ATB2L
      AL(I,J)=AL2L
      AR(I,J)=AR2L
      AF(I,J)=AF2L
      AB(I,J)=AB2L
      DF(I,J)=DF2L
      DB(I,J)=DB2L
      B1(I,J)=B12
   42 CØNTINUE
      GØ TØ 873
  188 DL2=(R*TH/2.0)*(SIN(PH1)+SIN(PH1+PH2))
      IF(N-32)270,270,21
  270 DØ 271 I=1,LL
      DØ 271 J=1,L
```

```
      IF(I-2)272,273,274
  274 IF(I-3)273,273,272
  272 PH(I,J)=PH1
      AL(I,J)=AL1
      AR(I,J)=AR1
      AF(I,J)=AF1
      AB(I,J)=AB1
      DL(I,J)=DL1
      DR(I,J)=DR1
      DF(I,J)=DF1
      DB(I,J)=DB1
      B1(I,J)=B11
      GØ TØ 271
  273 PH(I,J)=PH2
      AL(I,J)=AL2
      AR(I,J)=AR2
      AF(I,J)=AF2
      AB(I,J)=AB2
      DL(I,J)=DL2
      DR(I,J)=DR2
      DF(I,J)=DF2
      DB(I,J)=DB2
      BI(I,J)=BI2
  271 CØNTINUE
      GØ TØ 874
   21 PH3=(PI/2.)-(PH1+PH2)
      AL3=(R*PH3*A/B)*(1.-(A/(2.*R*B)))
      AR3=AL3
      AF3=(A*R*TH/B)*(1.-(A/(2.*B*R)))
      AB3=AF2
      DL3=(H/2.)+(R*TH/4.)*(SP2+1.)
      DR3=(R*TH/2.)*(SP2+1.)
      DF1=(R/2.)*(PH1+PH2)
      DF2=(R/2.)*(PH2+PH3)
      DF3=R*PH3
      DB3=DF2
      AT3L=R*PH3*H
      AU3L=AT3L
      ATB3L=2.*R*SIN(PH3/2.)*H
      AL3L=(R*PH3*A/B)*(1.-(A/(2.*B*R)))
      AR3L=AL3L
      AF3L=H*A/B
      AB3L=AF3L
      DL3L=(H/2.)+(R*TH/4.)*(SP2+1.)
      DR3L=DL3L
      DF1L=(R/2.)*(PH1+PH2)
      DF2L=(R/2.)*(PH2+PH3)
      DF3L=R*PH3
      DB1L=R*PH1
      DB2L=DF1L
      DB3L=DF2L
      VØL3L=(PH3/(2.*B))*H*(R**2-(R-A)**2)
      BI3=0.5*PH3+PH2+PH1
      ALP3=2.5*TH
      SN3=SIN(BI3)
      VZ31=SIN(ALP1)*SN3
```

```
      VZ13=SIN(ALP3)*SN1
      VZ23=SIN(ALP3)*SN2
      VZ32=SIN(ALP2)*SN3
      VZ33=SIN(ALP3)*SN3
      VY31=COS(ALP1)*SN3
      VY13=COS(ALP3)*SN1
      VY23=COS(ALP3)*SN2
      VY32=COS(ALP2)*SN3
      VY33=COS(ALP3)*SN3
      A31=ARKSIN(ABS(VZ31),IERR)
      A13=ARKSIN(ABS(VZ13),IERR)
      A23=ARKSIN(ABS(VZ23),IERR)
      A32=ARKSIN(ABS(VZ32),IERR)
      A33=ARKSIN(ABS(VZ33),IERR)
      IF(IERR)4,13,4
   13 VX3=COS(B13)
      AVX3=ABS(VX3)
      AVY31=ABS(VY31)
      AVY13=ABS(VY13)
      AVY23=ABS(VY23)
      AVY32=ABS(VY32)
      AVY33=ABS(VY33)
      AVZ31=ABS(VZ31)
      AVZ13=ABS(VZ13)
      AVZ23=ABS(VZ23)
      AVZ32=ABS(VZ32)
      AVZ33=ABS(VZ33)
      IF(FIG)900,901,901
  900 DO 46 I=1,6
      DO 46 J=1,13
      GO TO(47,48,49,49,48,47),I
   47 IF(J-7)52,46,52
   52 PH(I,J)=PH1
      AL(I,J)=AL1
      AR(I,J)=AR1
      AF(I,J)=AF1
      AB(I,J)=AB1
      DF(I,J)=DF1
      DB(I,J)=DB1
      B1(I,J)=B11
      GO TO 46
   48 IF(J-7)51,46,51
   51 PH(I,J)=PH2
      AL(I,J)=AL2
      AR(I,J)=AR2
      AF(I,J)=AF2
      AB(I,J)=AB2
      DF(I,J)=DF2
      DB(I,J)=DB2
      B1(I,J)=B12
      GO TO 46
   49 IF(J-7)50,46,50
   50 PH(I,J)=PH3
      AL(I,J)=AL3
      AR(I,J)=AR3
      AF(I,J)=AF3
```

```
      AB(I,J)=AB3
      DF(I,J)=DF3
      DB(I,J)=DB3
      BI(I,J)=BI3
   46 CØNTINUE
      DØ 63 I=1,6
      DØ 63 J=7,14,7
      GØ TØ(64,65,56,56,65,64),I
   64 PH(I,J)=PH1
      AT(I,J)=AT1L
      AU(I,J)=AU1L
      ATB(I,J)=ATB1L
      AL(I,J)=AL1L
      AR(I,J)=AR1L
      AF(I,J)=AF1L
      AB(I,J)=AB1L
      DF(I,J)=DF1L
      DB(I,J)=DB1L
      BI(I,J)=BI1
      GØ TØ 63
   65 PH(I,J)=PH2
      AT(I,J)=AT2L
      AU(I,J)=AU2L
      ATB(I,J)=ATB2L
      AL(I,J)=AL2L
      AR(I,J)=AR2L
      AF(I,J)=AF2L
      AB(I,J)=AB2L
      DF(I,J)=DF2L
      DB(I,J)=DB2L
      BI(I,J)=BI2
      GØ TØ 63
   56 PH(I,J)=PH3
      AT(I,J)=AT3L
      AU(I,J)=AU3L
      ATB(I,J)=ATB3L
      AL(I,J)=AL3L
      AR(I,J)=AR3L
      AF(I,J)=AF3L
      AB(I,J)=AB3L
      DF(I,J)=DF3L
      DB(I,J)=DB3L
      BI(I,J)=BI3
   63 CØNTINUE
      GØ TØ 873
  901 DL3=(R*TH/2.0)*(SIN(PH1+PH2)+1.0)
      DØ 902 I=1,LL
      DØ 902 J=1,L
      IF(I-2)903,904,905
  905 IF(I-4)906,906,907
  907 IF(I-6)904,903,903
  903 PH(I,J)=PH1
      AL(I,J)=AL1
      AR(I,J)=AR1
      AF(I,J)=AF1
      AB(I,J)=AB1
```

```
      DL(I,J)=DL1
      DR(I,J)=DR1
      DF(I,J)=DF1
      DB(I,J)=DB1
      B1(I,J)=B11
      GØ TØ 902
  904 PH(I,J)=PH2
      AL(I,J)=AL2
      AR(I,J)=AR2
      AF(I,J)=AF2
      AB(I,J)=AB2
      DL(I,J)=DL2
      DR(I,J)=DR2
      DF(I,J)=DF2
      DB(I,J)=DB2
      B1(I,J)=B12
      GØ TØ 902
  906 PH(I,J)=PH3
      AL(I,J)=AL3
      AR(I,J)=AR3
      AF(I,J)=AF3
      AB(I,J)=AB3
      DL(I,J)=DL3
      DR(I,J)=DR3
      DF(I,J)=DF3
      DB(I,J)=DB3
      B1(I,J)=B13
  902 CØNTINUE
      GØ TØ 874
  873 DØ 26 I=1,LL
      DØ 26 J=1,L
      IF(N-32)60,61,62
   60 IF(J-3)66,26,67
   67 IF(J-6)66,26,66
   61 IF(J-5)66,26,68
   68 IF(J-10)66,26,66
   62 IF(J-7)66,26,69
   69 IF(J-14)66,26,66
   66 AT(I,J)=AT1
      AU(I,J)=AU1
      ATB(I,J)=ATB1
   26 CØNTINUE
      GØ TØ 18
  874 DØ 872 I=1,LL
      DØ 872 J=1,L
      AT(I,J)=AT1
      AU(I,J)=AU1
      ATB(I,J)=ATB1
  872 CØNTINUE
   18 DØ 25 I=1,LL
      DØ 25 J=1,L
      DT(I,J)=DT1
      DU(I,J)=DU1
   25 CØNTINUE
      IF(FIG)152,153,153
  152 DØ 151 I=1,LL
```

```
      DØ 151 J=1,L
      IF(N-32)154,155,156
  154 GØ TØ(157,158,159,157,158,159),J
  157 DL(I,J)=DL1
      GØ TØ 160
  158 DL(I,J)=DR1
      GØ TØ 160
  159 DL(I,J)=DL1L
      GØ TØ 160
  155 GØ TØ(161,162,162,161),I
  161 GØ TØ(157,158,158,158,159,157,158,158,158,159),J
  162 GØ TØ(163,164,164,164,165,163,164,164,164,165),J
  163 DL(I,J)=DL2
      GØ TØ 160
  164 DL(I,J)=DR2
      GØ TØ 160
  165 DL(I,J)=DL2L
      GØ TØ 160
  156 GØ TØ(170,171,172,172,171,170),I
  170 GØ TØ(157,158,158,158,158,158,159,157,158,158,158,158,158,159),J
  171 GØ TØ(163,164,164,164,164,164,165,163,164,164,164,164,164,165),J
  172 GØ TØ(173,174,174,174,174,174,175,173,174,174,174,174,174,175),J
  173 DL(I,J)=DL3
      GØ TØ 160
  174 DL(I,J)=DR3
      GØ TØ 160
  175 DL(I,J)=DL3L
  160 IF(N-32)176,177,178
  176 GØ TØ(179,180,181,179,180,181),J
  179 DR(I,J)=DR1
      GØ TØ 151
  180 DR(I,J)=DL1
      GØ TØ 151
  181 DR(I,J)=DR1L
      GØ TØ 151
  177 GØ TØ(182,183,183,182),I
  182 GØ TØ(179,179,179,180,181,179,179,179,180,181),J
  183 GØ TØ(184,184,184,185,186,184,184,184,185,186),J
  184 DR(I,J)=DR2
      GØ TØ 151
  185 DR(I,J)=DL2
      GØ TØ 151
  186 DR(I,J)=DR2L
      GØ TØ 151
  178 GØ TØ(189,190,191,191,190,189),I
  189 GØ TØ(179,179,179,179,179,180,181,179,179,179,179,179,180,181),J
  190 GØ TØ(184,184,184,184,184,185,186,184,184,184,184,184,185,186),J
  191 GØ TØ(192,192,192,192,192,193,194,192,192,192,192,192,193,194),J
  192 DR(I,J)=DR3
      GØ TØ 151
  193 DR(I,J)=DL3
      GØ TØ 151
  194 DR(I,J)=DR3L
  151 CØNTINUE
  153 DØ 400 I=1,LL
      DØ 400 J=1,L
```

```
      IF(FIG)401,402,402
401   IF(N-32)403,404,405
403   GØ TØ(406,406,407,406,406,407),J
406   ALP(I,J)=ALP1
      GØ TØ 400
407   ALP(I,J)=0.0
      GØ TØ 400
404   GØ TØ(406,412,412,406,407,406,412,412,406,407),J
412   ALP(I,J)=ALP2
      GØ TØ 400
405   GØ TØ(406,412,422,422,412,406,407,406,412,422,422,412,406,407),J
422   ALP(I,J)=ALP3
      GØ TØ 400
402   IF(N-32)406,424,425
424   GØ TØ(406,412,412,406,406,412,412,406),J
425   GØ TØ(406,412,422,422,412,406,406,412,422,422,412,406),J
400   CØNTINUE
      DØ 430 I=1,LL
      DØ 430 J=1,L
      IF(FIG)431,432,432
431   IF(N-32)436,437,438
436   GØ TØ(433,433,434,433,433,434),J
433   A1(I,J)=A11
      GØ TØ 430
434   A1(I,J)=0.0
      GØ TØ 430
437   GØ TØ(439,440,440,439),I
439   GØ TØ(433,442,442,433,434,433,442,442,433,434),J
442   A1(I,J)=A12
      GØ TØ 430
440   GØ TØ(447,448,448,447,434,447,448,448,447,434),J
447   A1(I,J)=A21
      GØ TØ 430
448   A1(I,J)=A22
      GØ TØ 430
438   GØ TØ(453,454,456,456,454,453),I
453   GØ TØ(433,442,459,459,442,433,434,433,442,459,459,442,433,434),J
459   A1(I,J)=A13
      GØ TØ 430
454   GØ TØ(447,448,466,466,448,447,434,447,448,466,466,448,447,434),J
466   A1(I,J)=A23
      GØ TØ 430
456   GØ TØ(472,473,475,475,473,472,434,472,473,475,475,473,472,434),J
472   A1(I,J)=A31
      GØ TØ 430
473   A1(I,J)=A32
      GØ TØ 430
475   A1(I,J)=A33
      GØ TØ 430
432   IF(N-32)433,481,482
481   GØ TØ(483,484,484,483),I
483   GØ TØ(433,442,442,433,433,442,442,433),J
484   GØ TØ(447,448,448,447,447,448,448,447),J
482   GØ TØ(492,493,495,495,493,492),I
492   GØ TØ(433,442,459,459,442,433,433,442,459,459,442,433),J
493   GØ TØ(447,448,466,466,448,447,447,448,466,466,448,447),J
```

```
495 GØ TØ(472,473,475,475,473,472,472,473,475,475,473,472),J
430 CØNTINUE
    DØ 550 I=1,LL
    DØ 550 J=1,L
    IF(FIG)551,552,552
552 IF(N-32)553,554,556
553 GØ TØ(557,558,558,557),J
557 VY(I,J)=AVY11
    GØ TØ 550
558 VY(I,J)=-AVY11
    GØ TØ 550
554 GØ TØ(560,561,561,560),I
560 GØ TØ(557,562,564,558,558,564,562,557),J
562 VY(I,J)=AVY12
    GØ TØ 550
564 VY(I,J)=-AVY12
    GØ TØ 550
561 GØ TØ(567,568,570,571,571,570,568,567),J
567 VY(I,J)=AVY21
    GØ TØ 550
568 VY(I,J)=AVY22
    GØ TØ 550
570 VY(I,J)=-AVY22
    GØ TØ 550
571 VY(I,J)=-AVY21
    GØ TØ 550
556 GØ TØ(574,575,577,577,575,574),I
574 GØ TØ(557,562,580,581,564,558,558,564,581,580,562,557),J
580 VY(I,J)=AVY13
    GØ TØ 550
581 VY(I,J)=-AVY13
    GØ TØ 550
575 GØ TØ(567,568,587,588,570,571,571,570,588,587,568,567),J
587 VY(I,J)=AVY23
    GØ TØ 550
588 VY(I,J)=-AVY23
    GØ TØ 550
577 GØ TØ(593,594,596,597,599,600,600,599,597,596,594,593),J
593 VY(I,J)=AVY31
    GØ TØ 550
594 VY(I,J)=AVY32
    GØ TØ 550
596 VY(I,J)=AVY33
    GØ TØ 550
597 VY(I,J)=-AVY33
    GØ TØ 550
599 VY(I,J)=-AVY32
    GØ TØ 550
600 VY(I,J)=-AVY31
    GØ TØ 550
551 IF(N-32)604,605,606
604 GØ TØ(557,558,558,558,557,557),J
605 GØ TØ(609,610,610,609),I
609 GØ TØ(557,562,564,558,558,558,564,562,557,557),J
610 GØ TØ(567,568,570,571,571,571,570,568,567,567),J
606 GØ TØ(620,621,623,623,621,620),I
```

```
620 GØ TØ(557,562,580,581,571,558,558,558,571,581,580,562,557,557),J
621 GØ TØ(567,568,587,588,570,571,571,571,570,588,587,568,567,567),J
623 GØ TØ(593,594,596,597,599,600,600,600,599,597,596,594,593,593),J
550 CØNTINUE
    DØ 640 I=1,LL
    DØ 640 J=1,L
    IF(FIG)641,642,642
642 IF(N-32)643,644,645
643 GØ TØ(646,646,647,647),J
646 VZ(I,J)=AVZ11
    GØ TØ 640
647 VZ(I,J)=-AVZ11
    GØ TØ 640
644 GØ TØ(648,649,649,648),I
648 GØ TØ(646,651,651,646,647,654,654,647),J
651 VZ(I,J)=AVZ12
    GØ TØ 640
654 VZ(I,J)=-AVZ12
    GØ TØ 640
649 GØ TØ(656,657,657,656,660,661,661,660),J
656 VZ(I,J)=AVZ21
    GØ TØ 640
657 VZ(I,J)=AVZ22
    GØ TØ 640
660 VZ(I,J)=-AVZ21
    GØ TØ 640
661 VZ(I,J)=-AVZ22
    GØ TØ 640
645 GØ TØ(663,664,666,666,664,663),I
663 GØ TØ(646,651,669,669,651,646,647,654,673,673,654,647),J
669 VZ(I,J)=AVZ13
    GØ TØ 640
673 VZ(I,J)=-AVZ13
    GØ TØ 640
664 GØ TØ(656,657,676,676,657,656,660,661,680,680,661,656),J
676 VZ(I,J)=AVZ23
    GØ TØ 640
680 VZ(I,J)=-AVZ23
    GØ TØ 640
666 GØ TØ(682,683,685,685,683,682,688,689,691,691,689,688),J
682 VZ(I,J)=AVZ31
    GØ TØ 640
683 VZ(I,J)=AVZ32
    GØ TØ 640
685 VZ(I,J)=AVZ33
    GØ TØ 640
688 VZ(I,J)=-AVZ31
    GØ TØ 640
689 VZ(I,J)=-AVZ32
    GØ TØ 640
691 VZ(I,J)=-AVZ33
    GØ TØ 640
641 IF(N-32)693,694,695
693 GØ TØ(646,646,696,647,647,696),J
696 VZ(I,J)=0.0
    GØ TØ 640
```

```
694 GØ TØ(698,699,699,698),I
698 GØ TØ(646,651,651,646,696,647,654,654,647,696),J
699 GØ TØ(656,657,657,656,696,660,661,661,660,696),J
695 GØ TØ(709,710,712,712,710,709),I
709 GØ TØ(646,651,669,669,651,646,696,647,654,673,673,654,647,696),J
710 GØ TØ(656,657,676,676,657,656,696,660,661,680,680,661,660,696),J
712 GØ TØ(682,683,685,685,683,682,696,688,689,691,691,689,688,696),J
640 CØNTINUE
    DØ 15 I=1,LL
    DØ 15 J=1,L
    IF(FIG)16,17,17
 17 VØL(I,J)=VØL1
    GØ TØ 15
 16 IF(N-32)22,23,24
 22 GØ TØ(17,17,110,17,17,110),J
110 VØL(I,J)=VØL1L
    GØ TØ 15
 23 GØ TØ(111,112,112,111),I
111 GØ TØ(17,17,17,17,110,17,17,17,17,110),J
112 GØ TØ(17,17,17,17,113,17,17,17,17,113),J
113 VØL(I,J)=VØL2L
    GØ TØ 15
 24 GØ TØ(207,208,209,209,208,207),I
207 GØ TØ(17,17,17,17,17,17,110,17,17,17,17,17,17,110),J
208 GØ TØ(17,17,17,17,17,17,113,17,17,17,17,17,17,113),J
209 GØ TØ(17,17,17,17,17,17,210,17,17,17,17,17,17,210),J
210 VØL(I,J)=VØL3L
 15 CØNTINUE
    DØ 740 I=1,LL
    DØ 740 J=1,L
    IF(FIG)741,742,742
741 IF(N-32)743,744,745
743 IF(I-2)746,747,747
746 VX(I,J)=AVX1
    GØ TØ 748
747 VX(I,J)=-AVX1
    GØ TØ 748
744 IF(I-2)746,749,750
750 IF(I-4)751,747,747
749 VX(I,J)=AVX2
    GØ TØ 748
751 VX(I,J)=-AVX2
    GØ TØ 748
745 IF(I-2)746,749,752
752 IF(I-4)753,754,755
755 IF(I-6)751,747,747
753 VX(I,J)=AVX3
    GØ TØ 748
754 VX(I,J)=-AVX3
    GØ TØ 748
742 IF(N-32)756,757,758
756 IF(I-2)746,747,747
757 IF(I-2)746,749,759
759 IF(I-4)751,747,747
758 IF(I-2)746,749,760
760 IF(I-4)753,754,761
```

```
761 IF(I-6)751,747,747
748 V(I,J)=VX(I,J)+VY(I,J)+VZ(I,J)
740 CØNTINUE
    DØ 762 I=1,LL
    DØ 762 J=I,L
    IF(FIG)763,764,764
763 IF(N-32)765,766,767
764 IF(N-32)765,766,767
765 IF(J-3)768,769,769
766 IF(J-5)768,769,769
767 IF(J-7)768,769,769
768 GA(I,J)=ABS(PI/2.+A1(I,J))
    GØ TØ 770
769 GA(I,J)=ABS(PI/2.-A1(I,J))
770 IF(IERR)771,762,771
771 WRITE(6,772)
772 FØRMAT(//8X,15HERRØR IN ARKCØS)
762 CØNTINUE
    RETURN
    END
```

```
      SUBRØUTINE DK200(AN,LL,L,TH)
      CØMMØN AT(6,14),AU(6,14),AL(6,14),AR(6,14),AF(6,14),AB(6,14),ATB(6
     C,14),ALP(6,14),A1(6,14),B1(6,14),DT(6,14),DU(6,14),DB(6,14),DF(6,1
     C4),DR(6,14),DL(6,14),GA(6,14),PH(6,14),V(6,14),VX(6,14),VY(6,14),V
     CZ(6,14),AØDL(6,14),AØDR(6,14),AØDF(6,14),AØDB(6,14),AØDT(6,14),AØD
     CU(6,14),VØL(6,14),NE(14),N,FIG,A,B,H,R
      PI=3.14159
  120 PH1=4.0*PI/AN
      ATM=R*PH1*H
      ATE=(2.*PI*R**2)/AN
      AUM=ATM
      AUE=ATE
      ATBM=2.*R*H*SIN(PH1/2.0)
      ATBE=ATE
      VØLE=(2.*PI*R**2*A)/(AN*B)
      VØLM=((2.*PI*H)/(AN*B))*(R**2-(R-A)**2)
      ALM=R*PH1*A/B
      ALE=0.0
      ARM=ALM
      ARE=R*PH1*A/B
      AFM=H*A/B
      AFE=R*A/B
      ABM=AFM
      ABE=AFE
      DLM=H/2.+R/3.
      DLE=(2./3.)*R
      DRM=DLM
      DRE=DLM
      DFM=R*PH1
      DFE=(8.*PI*R)/(3.*AN)
      DBM=DFM
      DBE=DFE
      DTM=A/B
      DTE=DTM
      DUM=DTM
      DUE=DTM
      A1M=0.0
      A1E=PI/2.0
      B1M=(1.0/2.0)*PH1
      B1E=0.0
      VXM=CØS(B1M)
      VXE=0.0
      VYM=SIN(B1M)
      VYE=0.0
      VZM=0.0
      VZE=1.0
      DØ 121 I=1,LL
      DØ 121 J=1,L
      IF(I-N/8)122,122,123
  122 VX(I,J)=VXM
      GØ TØ 124
  123 VX(I,J)=-VXM
  124 IF(J-1)125,125,126
  126 IF(J-4)127,127,125
  125 VY(I,J)=VYM
```

```
      GØ TØ 121
  127 VY(I,J)=-VYM
  121 CØNTINUE
      DØ 128 I=1,LL
      DØ 128 J=1,L
      IF(J-2)129,129,130
  130 IF(J-3)131,131,132
  132 IF(J-6)133,131,131
  129 VZ(I,J)=VZE
      GØ TØ 128
  131 VZ(I,J)=VZM
      GØ TØ 128
  133 VZ(I,J)=-VZE
  128 CØNTINUE
      DØ 137 I=1,LL
      DØ 137 J=1,L
      IF(J-3)134,135,136
  136 IF(J-6)134,135,135
  134 PH(I,J)=PH1
      AT(I,J)=ATE
      AU(I,J)=AUE
      ATB(I,J)=ATBE
      AL(I,J)=ALE
      AR(I,J)=ARE
      AF(I,J)=AFE
      AB(I,J)=ABE
      DL(I,J)=DLE
      DR(I,J)=DRE
      DF(I,J)=DFE
      DB(I,J)=DBE
      DT(I,J)=DTE
      DU(I,J)=DUE
      ALP(I,J)=A1E
      B1(I,J)=B1E
      VX(I,J)=VXE
      VY(I,J)=VYE
      VØL(I,J)=VØLE
      GØ TØ 870
  135 PH(I,J)=PH1
      AT(I,J)=ATM
      AU(I,J)=AUM
      ATB(I,J)=ATBM
      AL(I,J)=ALM
      AR(I,J)=ARM
      AF(I,J)=AFM
      AB(I,J)=ABM
      DL(I,J)=DLM
      DR(I,J)=DRM
      DF(I,J)=DFM
      DB(I,J)=DBM
      DT(I,J)=DTM
      DU(I,J)=DUM
      ALP(I,J)=A1M
      B1(I,J)=B1M
      VØL(I,J)=VØLM
  870 V(I,J)=VX(I,J)+VY(I,J)+VZ(I,J)
```

```
 137 CØNTINUE
     DØ 14 I=1,LL
     DØ 14 J=1,L
  14 A1(I,J)=0.0
     DØ 138 I=1,LL
     DØ 138 J=1,L
     IF(J-3)139,140,141
 141 IF(J-5)142,142,143
 143 IF(J-6)142,140,140
 139 GA(I,J)=PI
     GØ TØ 138
 140 GA(I,J)=PI/2.0
     GØ TØ 138
 142 GA(I,J)=0.0
 138 CØNTINUE
     RETURN
     END
```

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COMPUTER PROGRAM-CRYOGENIC STORAGE
ON THE MOON (SUBROUTINE A AND C)

By

James K. Harrison

and

James W. Hilliard

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This document has also been reviewed and approved for technical accuracy.

Gerhard B. Heller

GERHARD B. HELLER
Dep. Director, Research Projects Division

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